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Peh et al.

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(54) **EQUI-JOINS BETWEEN SPLIT TABLES**

(71) Applicant: **SAP SE**, Walldorf (DE)

(72) Inventors: **Thomas Peh**, Heidelberg (DE); **Holger Schwedes**, Kraichtal (DE); **Wolfgang Stephan**, Heidelberg (DE)

(73) Assignee: **SAP SE**, Walldorf (DE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 13/117,894, filed on May 27, 2011, now Pat. No. 8,793,287.

(51) **Int. Cl.**
G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/30289*** (2013.01); ***G06F 17/30498*** (2013.01); ***G06F 17/30545*** (2013.01)

(58) **Field of Classification Search**
USPC 707/809
See application file for complete search history.

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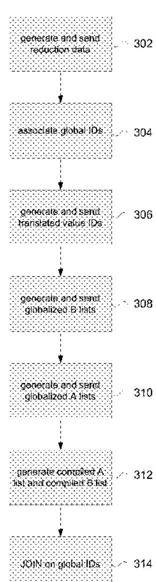
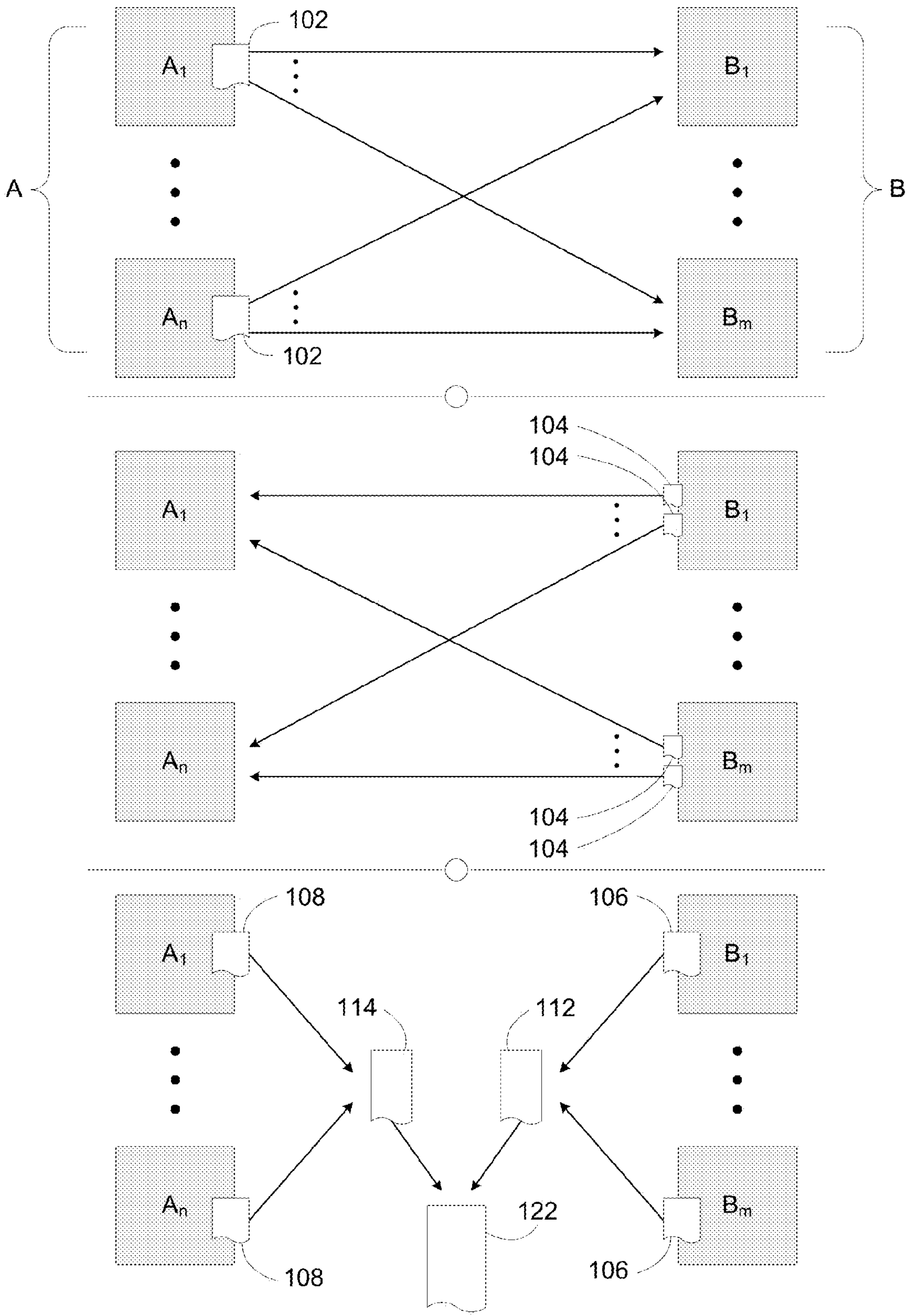
Primary Examiner — Rehana Perveen
Assistant Examiner — Tiffany Thuy Bui
(74) *Attorney, Agent, or Firm* — Fountainhead Law Group PC

(57) **ABSTRACT**

A join operation between split data tables includes providing reduction data from first partitions to each partition among second partitions. The reduction data serves to identify actual values in one of the second partitions that also occur in one of the first partitions. Global IDs are assigned. Translation lists including the global IDs are sent to the first partitions. Each first partition and each second partition create globalized lists which can then be combined to generate respective first and second compiled lists. The join operation can then be conducted on the first and second compiled lists.

18 Claims, 27 Drawing Sheets





102
A
A_1
B_1
B
A_n
B_m
102
104
104
A_1
B_1
A_n
B_m
104
104
108
106
A_1
B_1
114
112
A_n
B_m
122
108
106

Fig. 1

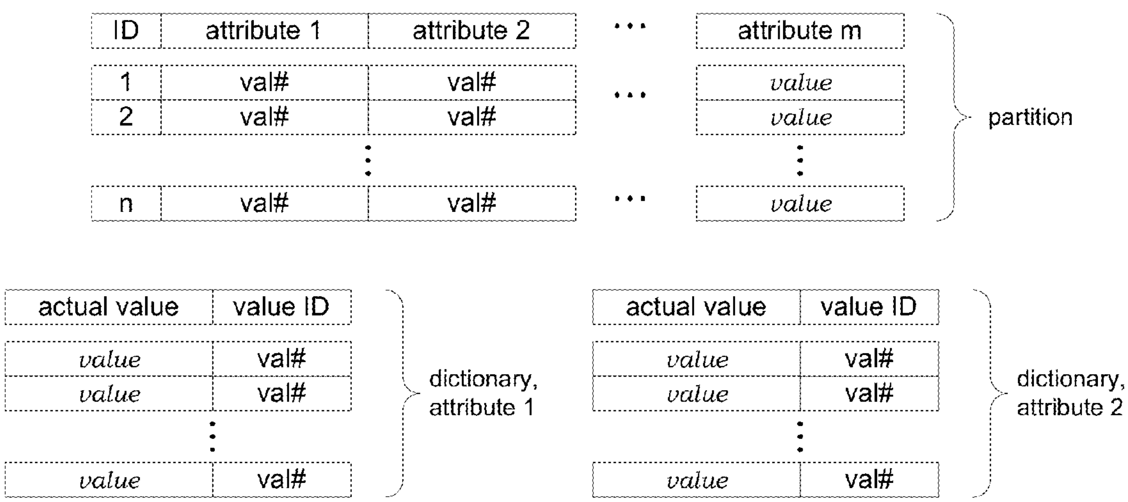

ID
attribute 1
attribute 2
attribute m
1
2
n
val#
value
partition
actual value
value ID
dictionary, attribute 1
dictionary, attribute 2

Fig. 1A

200

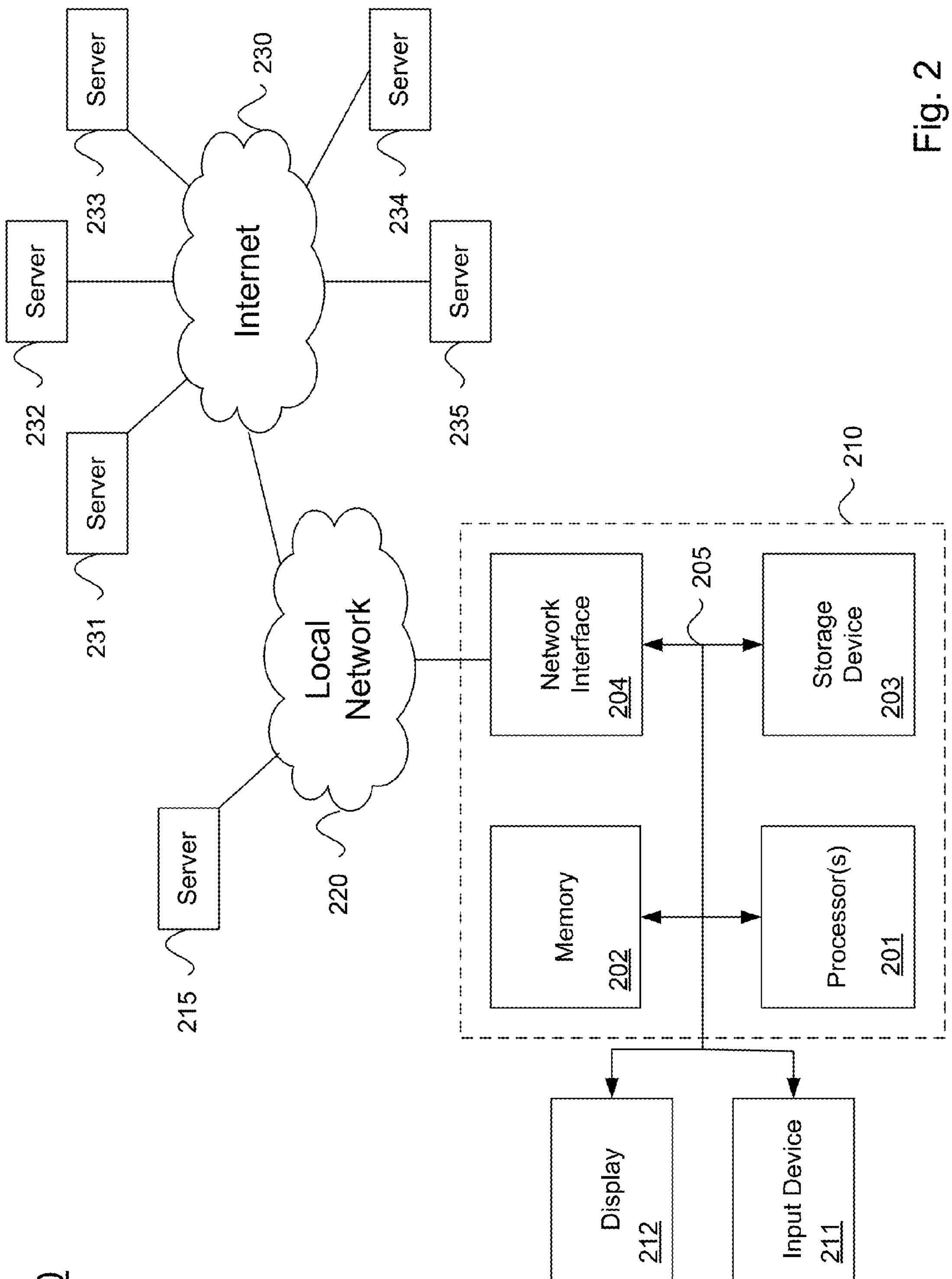

Server
233
Server
232
Server
231
Internet
230
Server
234
Server
235
Local Network
220
Server
215
Network Interface
204
205
Storage Device
203
Memory
202
Processor(s)
201
210
Display
212
Input Device
211

Fig. 2

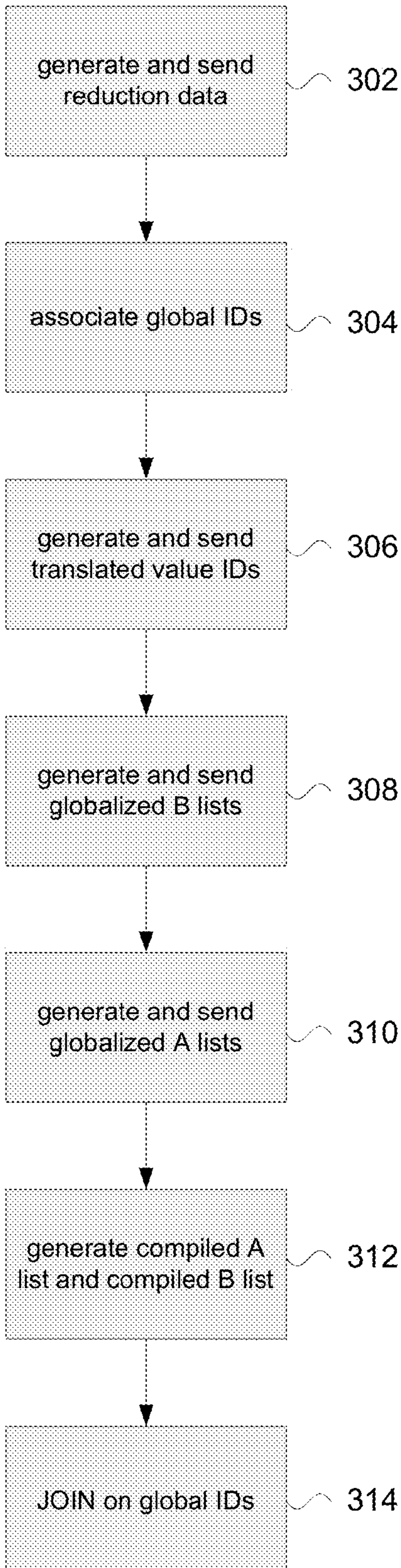

generate and send reduction data
302
associate global IDs
304
generate and send translated value IDs
306
generate and send globalized B lists
308
generate and send globalized A lists
310
generate compiled A list and compiled B list
312
JOIN on global IDs
314

Fig. 3

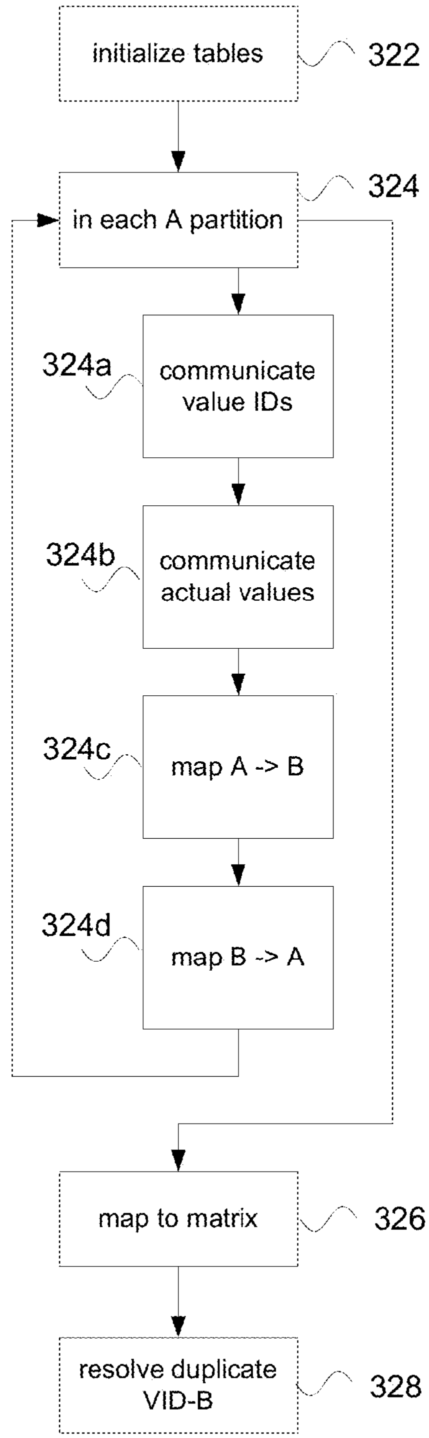

initialize tables
322
in each A partition
324
324a
communicate value IDs
324b
communicate actual values
324c
map A -> B
324d
map B -> A
map to matrix
326
resolve duplicate VID-B
328

Fig. 3A

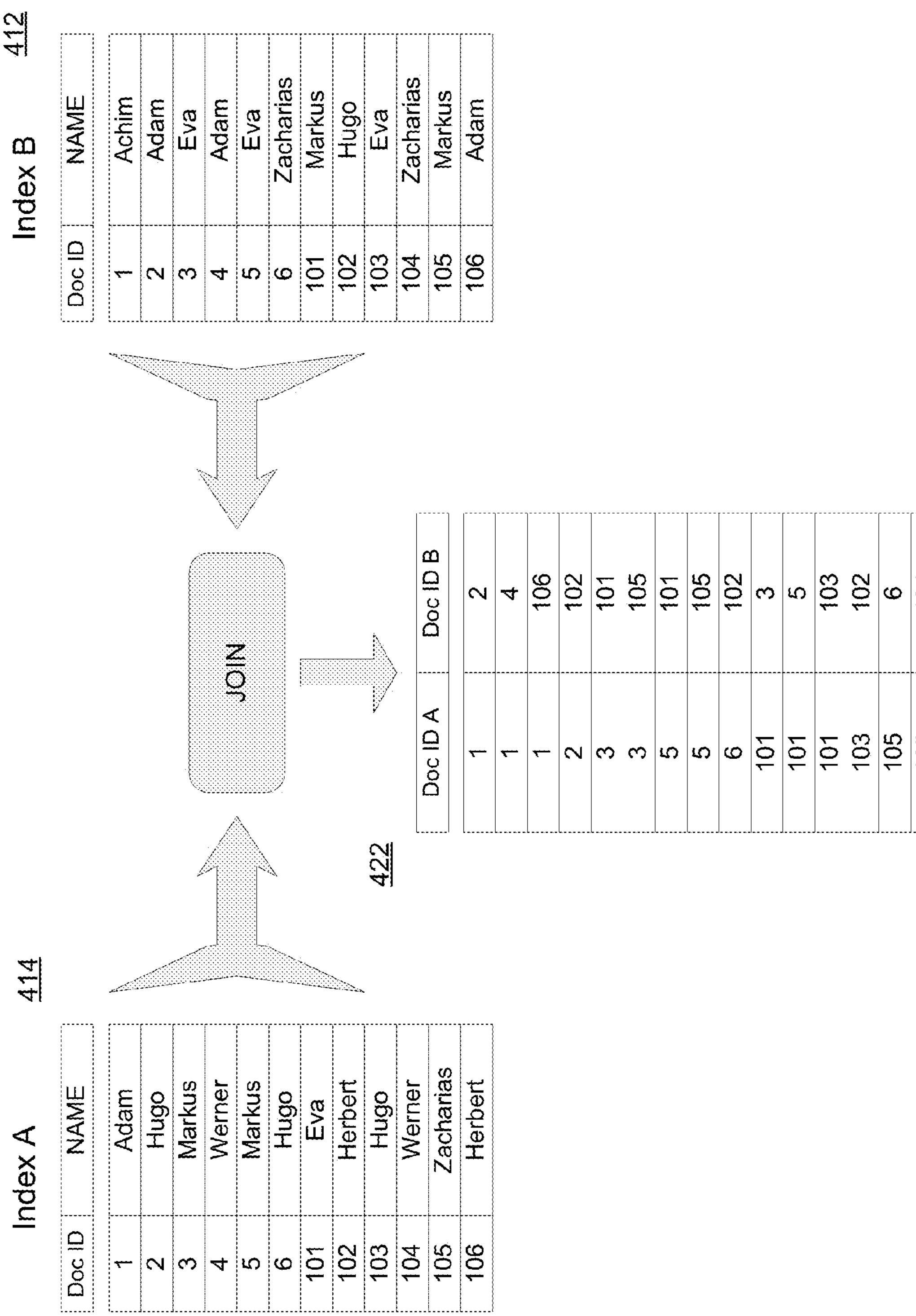
Data Table A 402

Doc ID	NAME	atrr 3	• • •	attr X
1	Adam	*value*		*value*
2	Hugo	*value*		*value*
3	Markus	*value*		*value*
4	Werner	*value*		*value*
5	Markus	*value*		*value*
6	Hugo	*value*		*value*
101	Eva	*value*		*value*
102	Herbert	*value*		*value*
103	Hugo	*value*		*value*
104	Werner	*value*		*value*
105	Zacharias	*value*		*value*
106	Herbert	*value*	• • •	*value*

Data Table B 404

Doc ID	NAME	atrr 3	• • •	attr Y
1	Achim	*value*		*value*
2	Adam	*value*		*value*
3	Eva	*value*		*value*
4	Adam	*value*		*value*
5	Eva	*value*		*value*
6	Zacharias	*value*		*value*
101	Markus	*value*		*value*
102	Hugo	*value*		*value*
103	Eva	*value*		*value*
104	Zacharias	*value*		*value*
105	Markus	*value*		*value*
106	Adam	*value*	• • •	*value*

Fig. 4



Index B (412)

Doc ID	NAME
1	Achim
2	Adam
3	Eva
4	Adam
5	Eva
6	Zacharias
101	Markus
102	Hugo
103	Eva
104	Zacharias
105	Markus
106	Adam

Index A (414)

Doc ID	NAME
1	Adam
2	Hugo
3	Markus
4	Werner
5	Markus
6	Hugo
101	Eva
102	Herbert
103	Hugo
104	Werner
105	Zacharias
106	Herbert

Join result (422)

Doc ID A	Doc ID B
1	2
1	4
1	106
2	102
3	101
3	105
5	101
5	105
6	102
101	3
101	5
101	103
103	102
105	6
105	104

Join result

Fig. 4A

502a

value ID	Doc ID	NAME	atrr 3	...	attr X
1	1	Adam	*value*		*value*
2	2	Hugo	*value*		*value*
3	3	Markus	*value*		*value*
4	4	Werner	*value*		*value*
3	5	Markus	*value*		*value*
2	6	Hugo	*value*	...	*value*

A_1

502b

value ID	Doc ID	NAME	atrr 3	...	attr X
1	101	Eva	*value*		*value*
2	102	Herbert	*value*		*value*
3	103	Hugo	*value*		*value*
4	104	Werner	*value*		*value*
5	105	Zacharias	*value*		*value*
2	106	Herbert	*value*	...	*value*

A_2

A

504a

value ID	Doc ID	NAME	atrr 3	...	attr Y
1	1	Achim	*value*		*value*
2	2	Adam	*value*		*value*
3	3	Eva	*value*		*value*
2	4	Adam	*value*		*value*
3	5	Eva	*value*		*value*
4	6	Zacharias	*value*	...	*value*

B_1

504b

value ID	Doc ID	NAME	atrr 3	...	attr Y
4	101	Markus	*value*		*value*
3	102	Hugo	*value*		*value*
2	103	Eva	*value*		*value*
5	104	Zacharias	*value*		*value*
4	105	Markus	*value*		*value*
1	106	Adam	*value*	...	*value*

B_2

B

Fig. 5

512a

NAME	value ID
Adam	1
Hugo	2
Markus	3
Werner	4

Dictionary A_1

514a

NAME	value ID
Achim	1
Adam	2
Eva	3
Zacharias	4

Dictionary B_1

512a

NAME	value ID
Eva	1
Herbert	2
Hugo	3
Werner	4
Zacharias	5

Dictionary A_2

514b

NAME	value ID
Adam	1
Eva	2
Hugo	3
Markus	4
Zacharias	5

Dictionary B_2

Fig. 5A

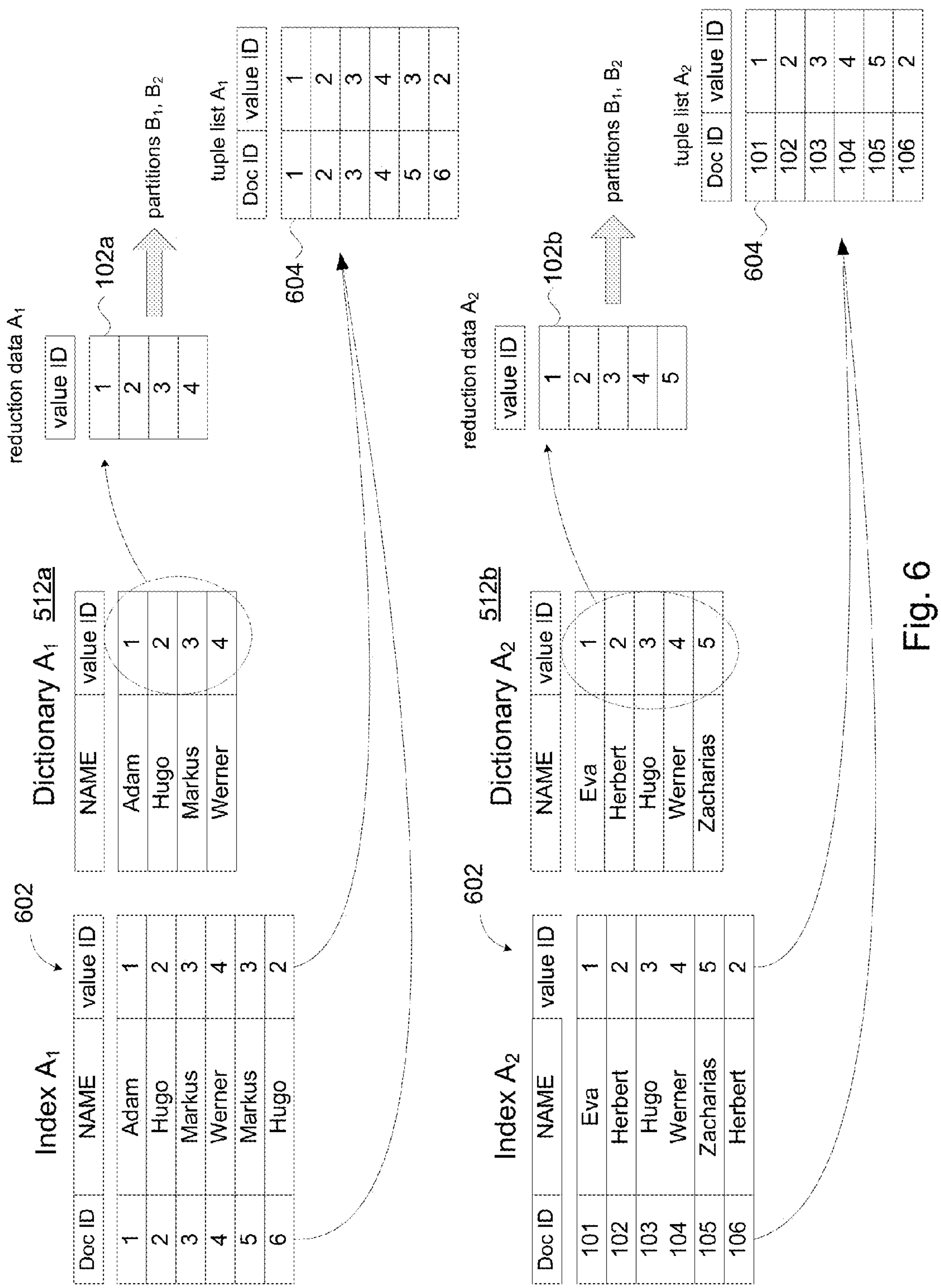

Index A_1
602
Doc ID | NAME | value ID
1 Adam 1
2 Hugo 2
3 Markus 3
4 Werner 4
5 Markus 3
6 Hugo 2
Dictionary A_1 512a
NAME | value ID
Adam 1
Hugo 2
Markus 3
Werner 4
reduction data A_1
value ID
1
2
3
4
102a
partitions B_1, B_2
tuple list A_1
Doc ID | value ID
1 1
2 2
3 3
4 4
5 3
6 2
604
Index A_2
602
Doc ID | NAME | value ID
101 Eva 1
102 Herbert 2
103 Hugo 3
104 Werner 4
105 Zacharias 5
106 Herbert 2
Dictionary A_2 512b
NAME | value ID
Eva 1
Herbert 2
Hugo 3
Werner 4
Zacharias 5
reduction data A_2
value ID
1
2
3
4
5
102b
partitions B_1, B_2
tuple list A_2
Doc ID | value ID
101 1
102 2
103 3
104 4
105 5
106 2
604

Fig. 6

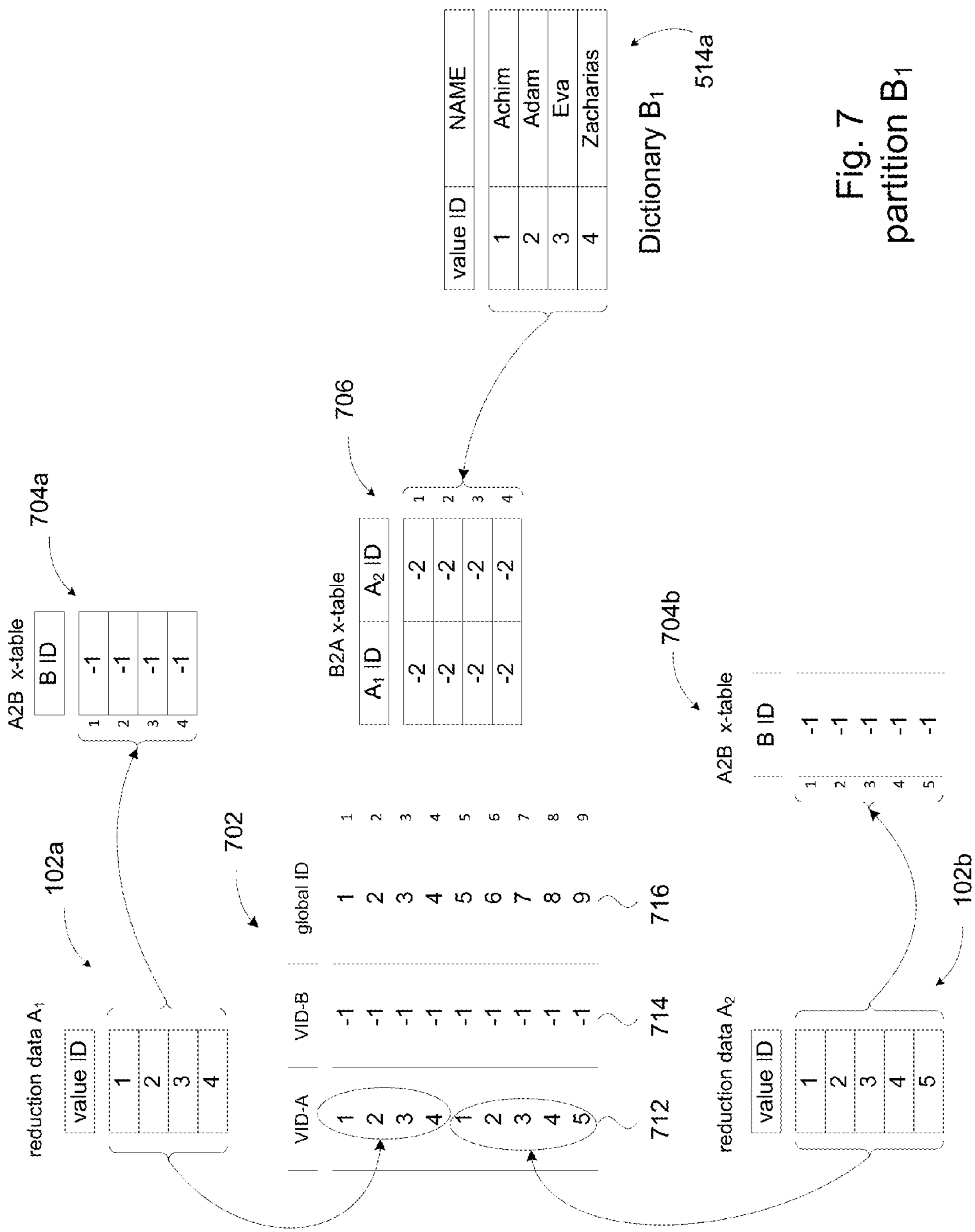


Fig. 7
partition B_1

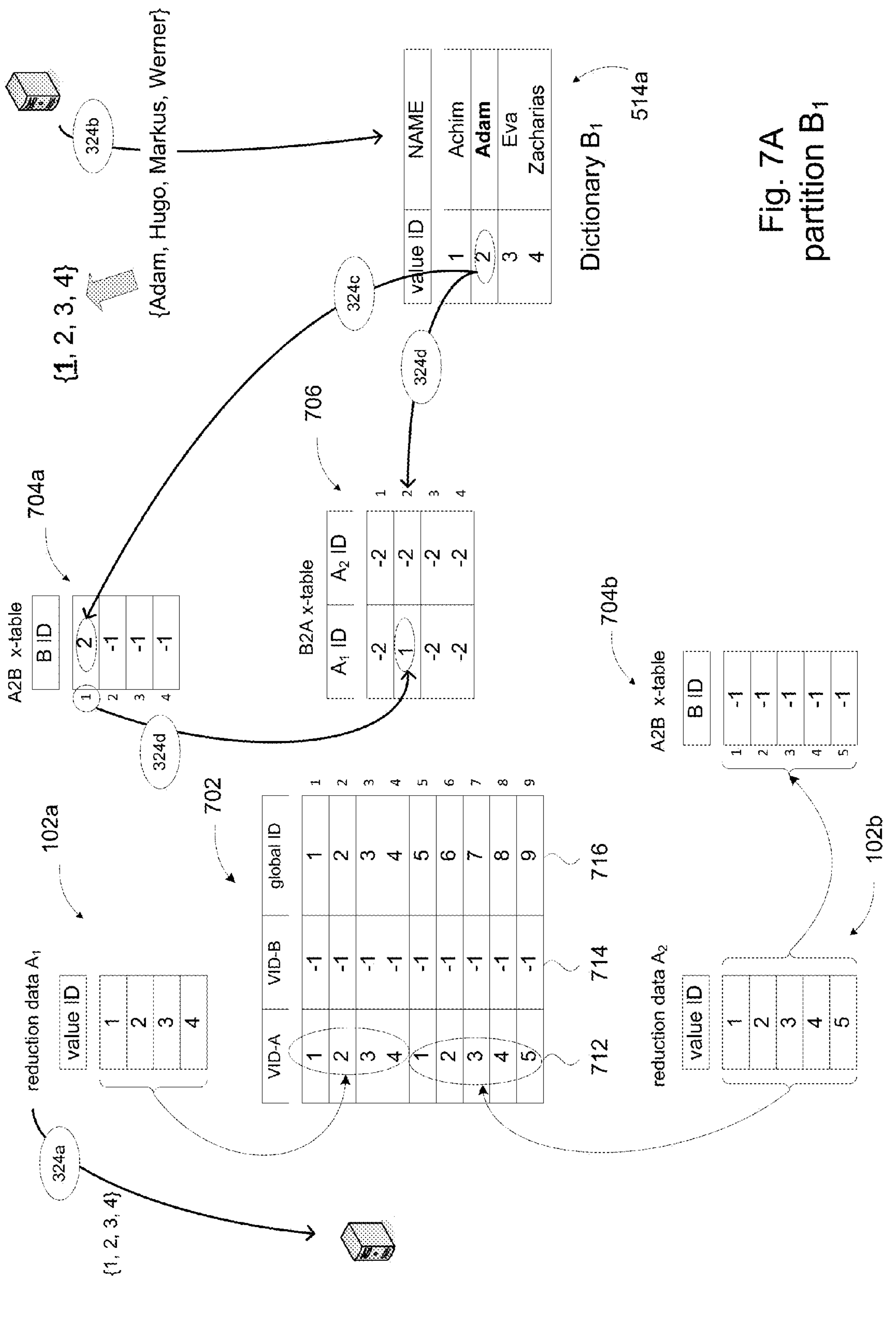


Fig. 7A
partition B_1

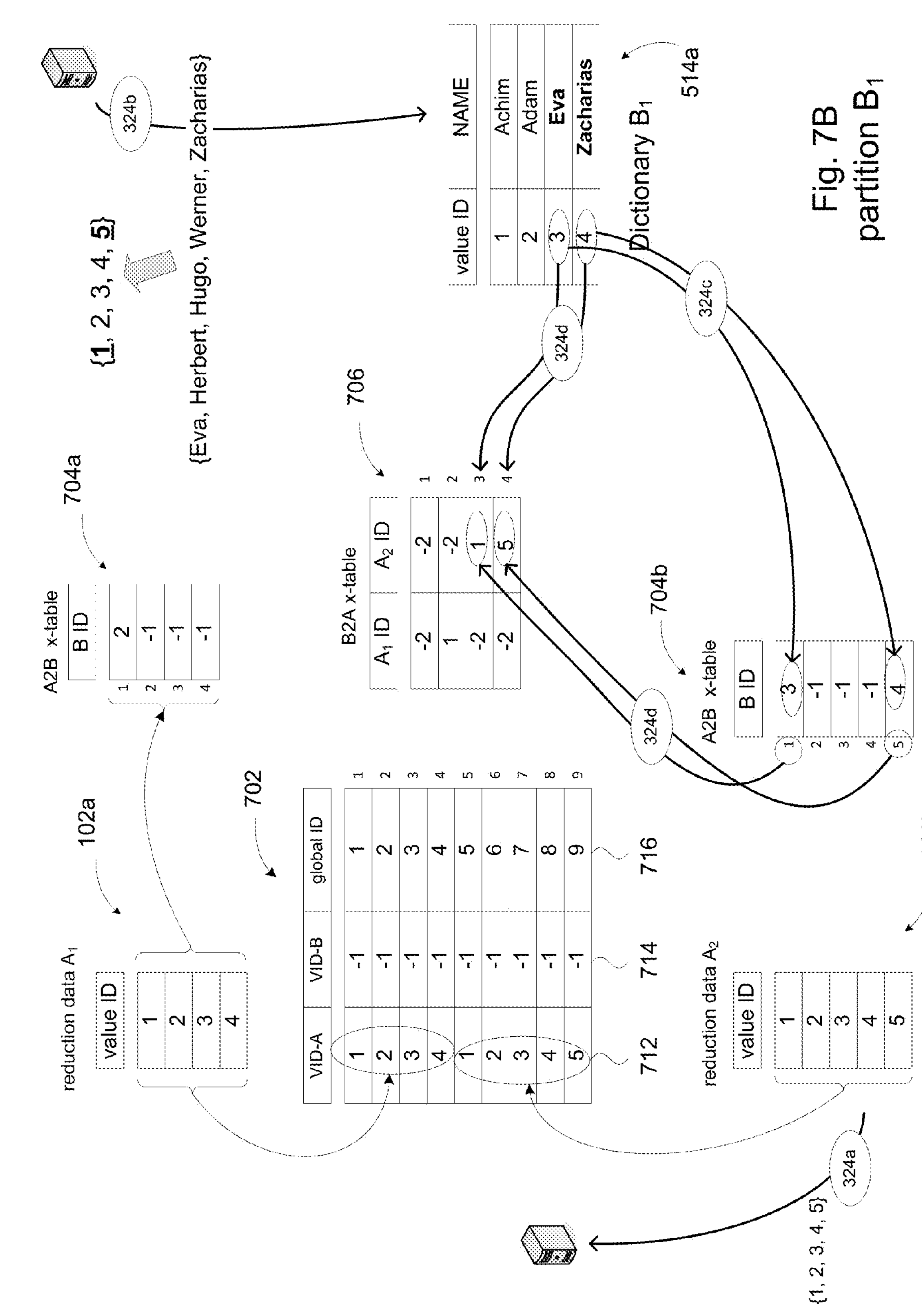


Fig. 7B
partition B_1

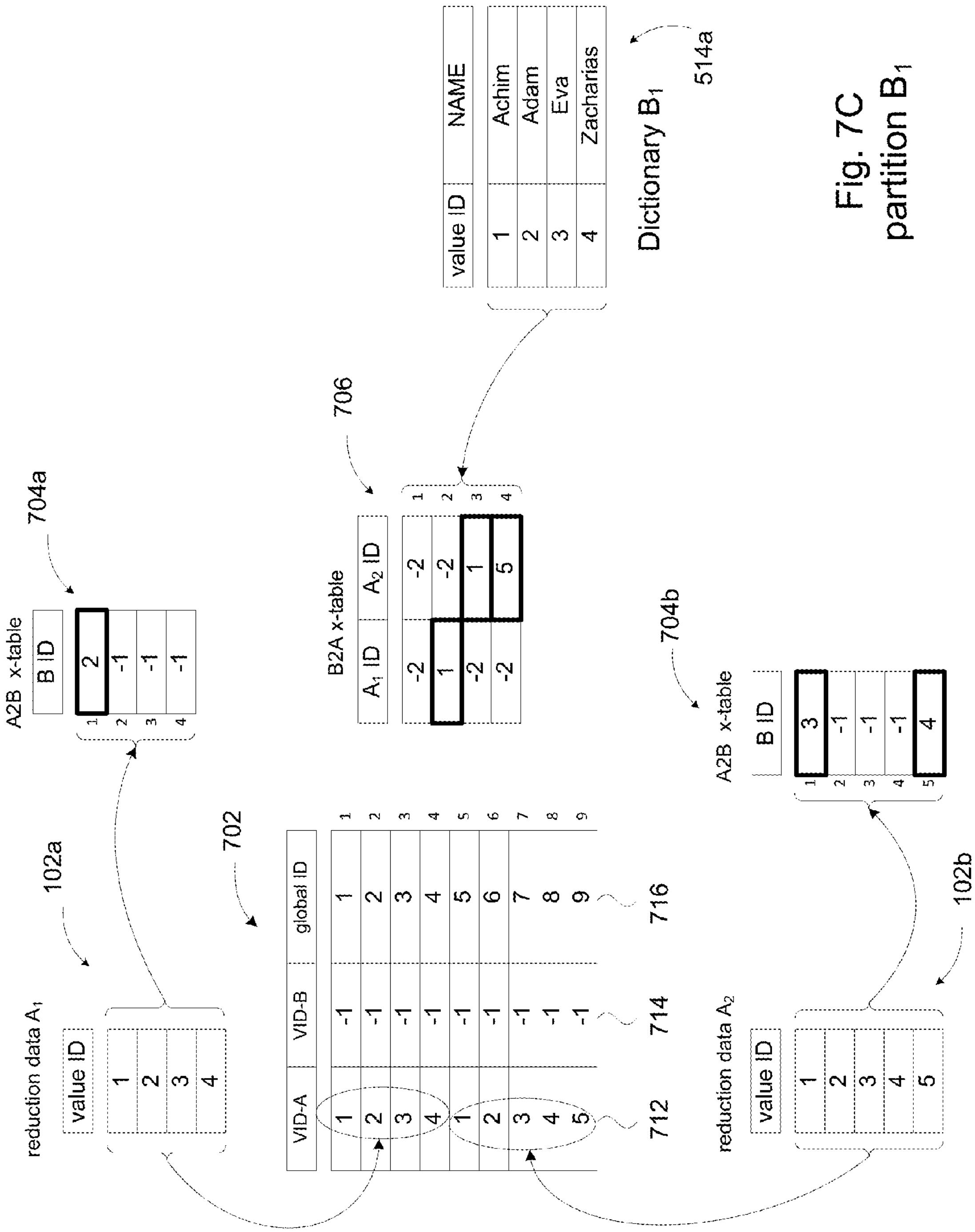


Fig. 7C
partition B_1

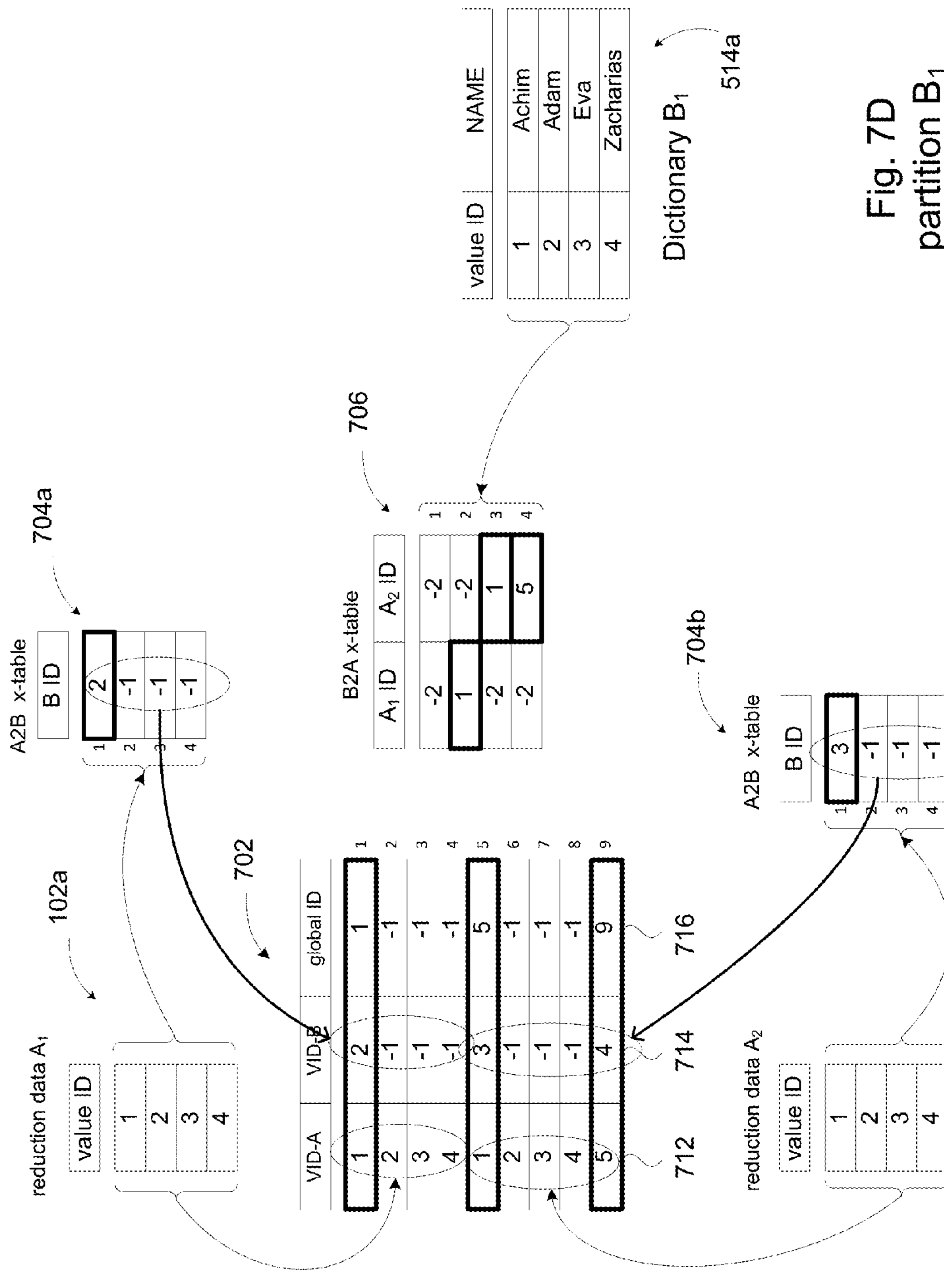


Fig. 7D
partition B_1

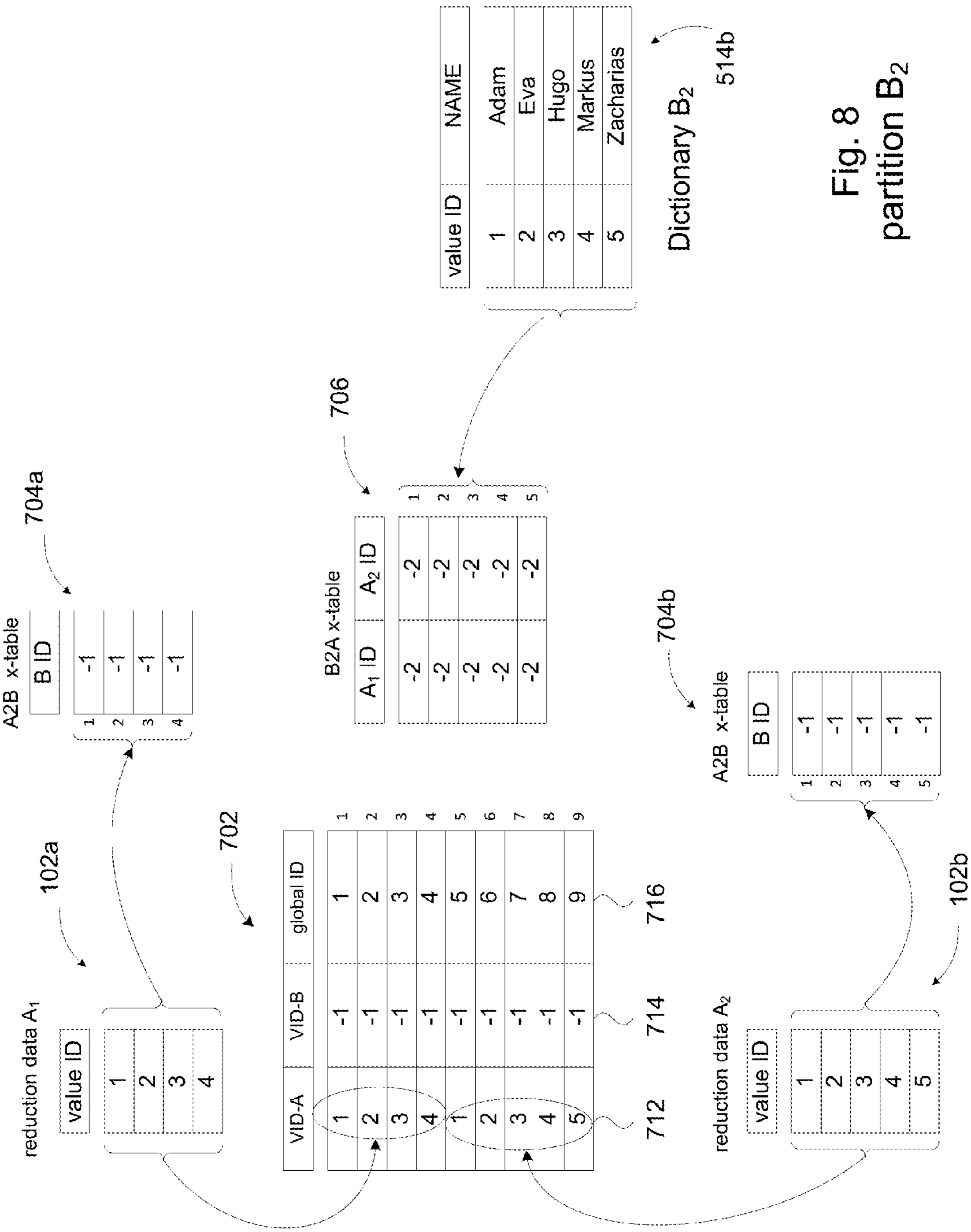


Fig. 8
partition B_2

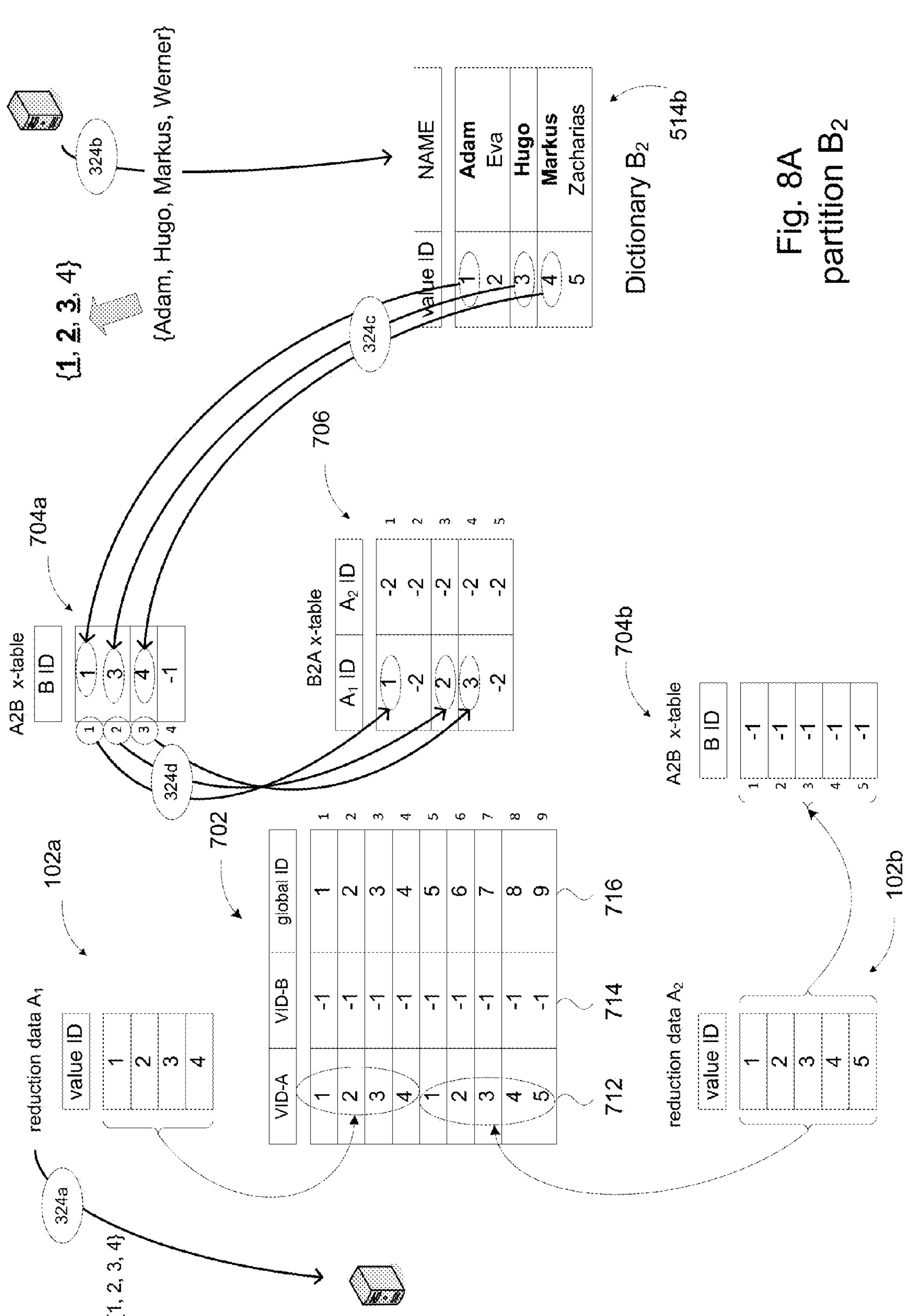


Fig. 8A
partition B_2

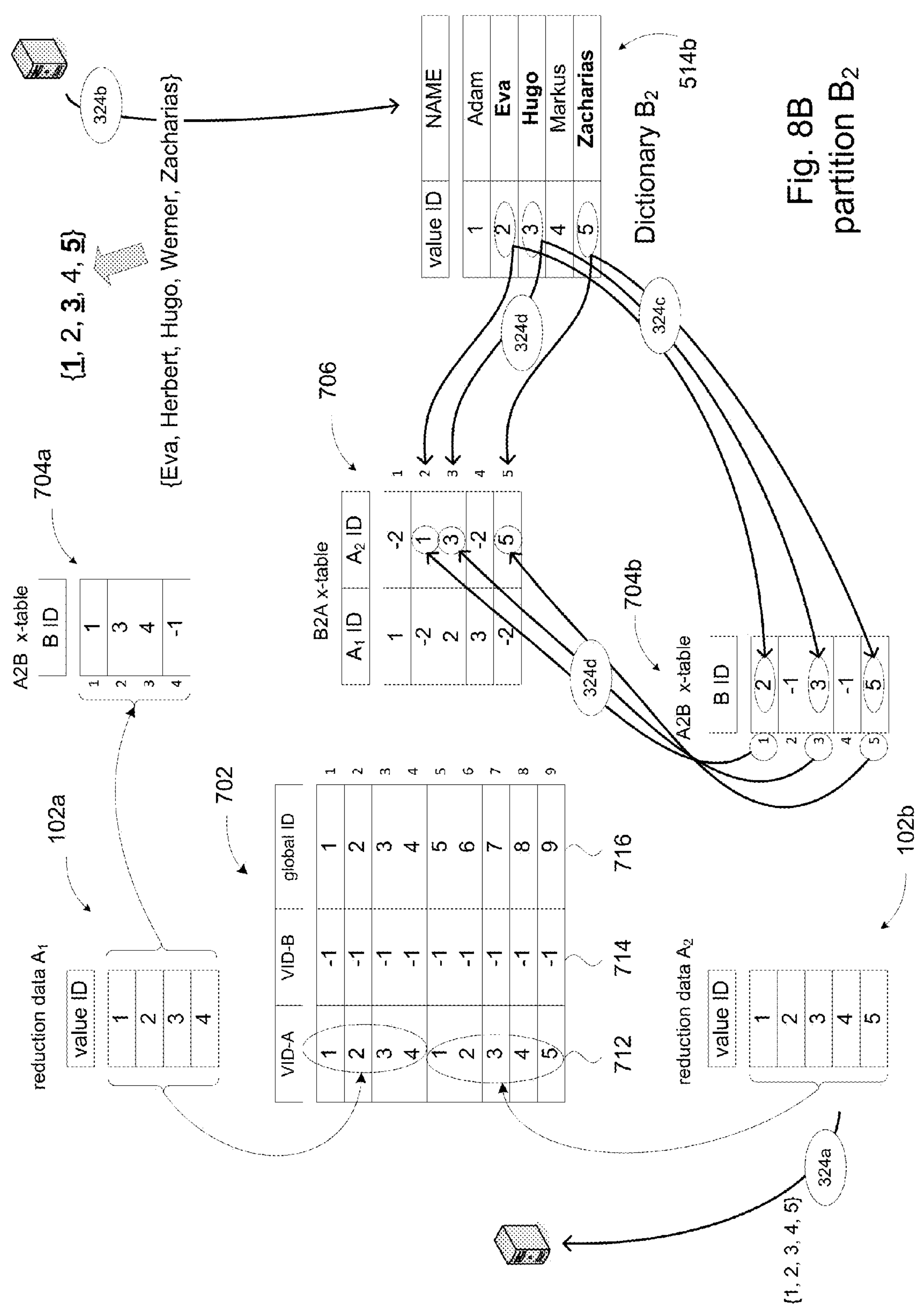


Fig. 8B
partition B_2

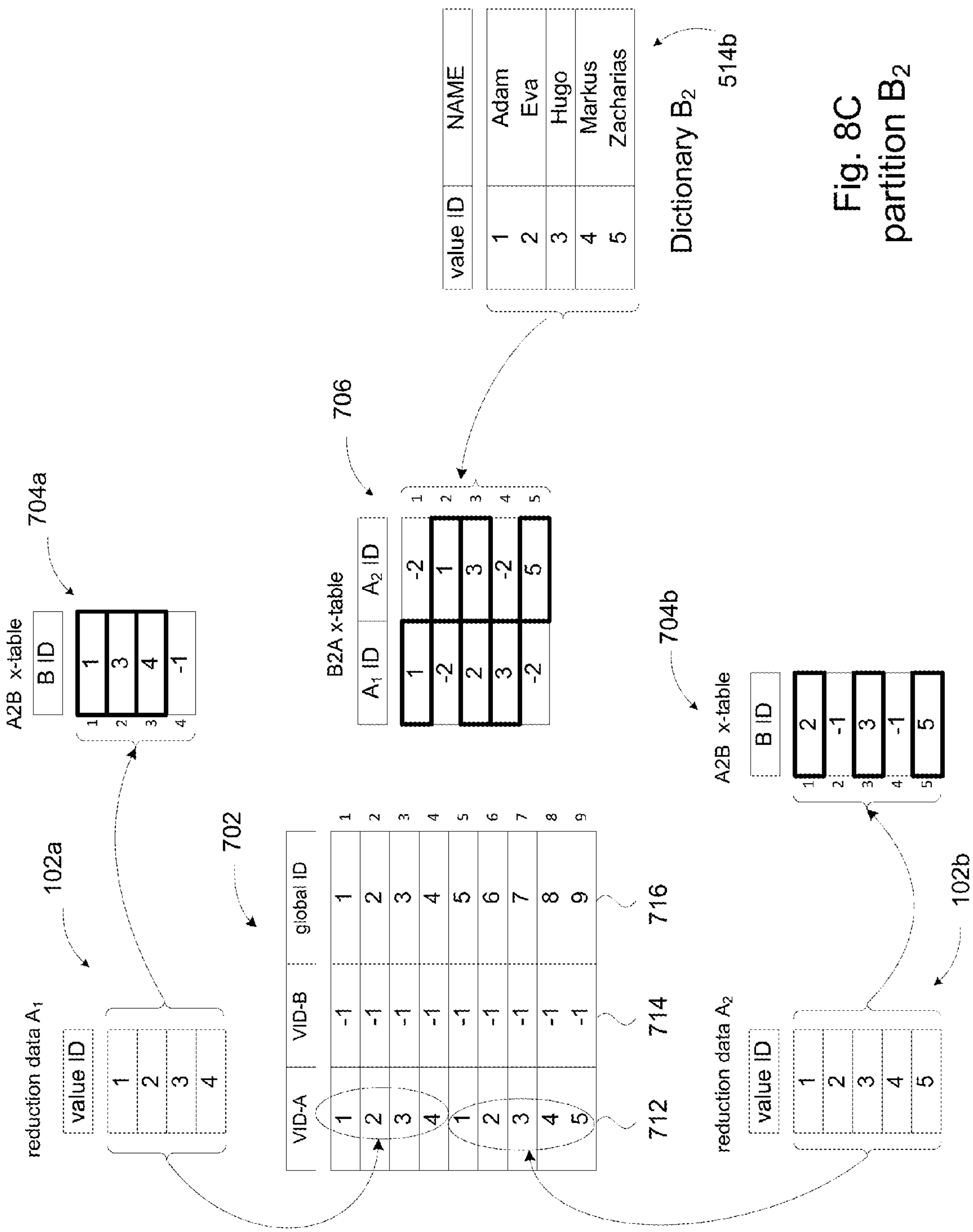


Fig. 8C
partition B_2

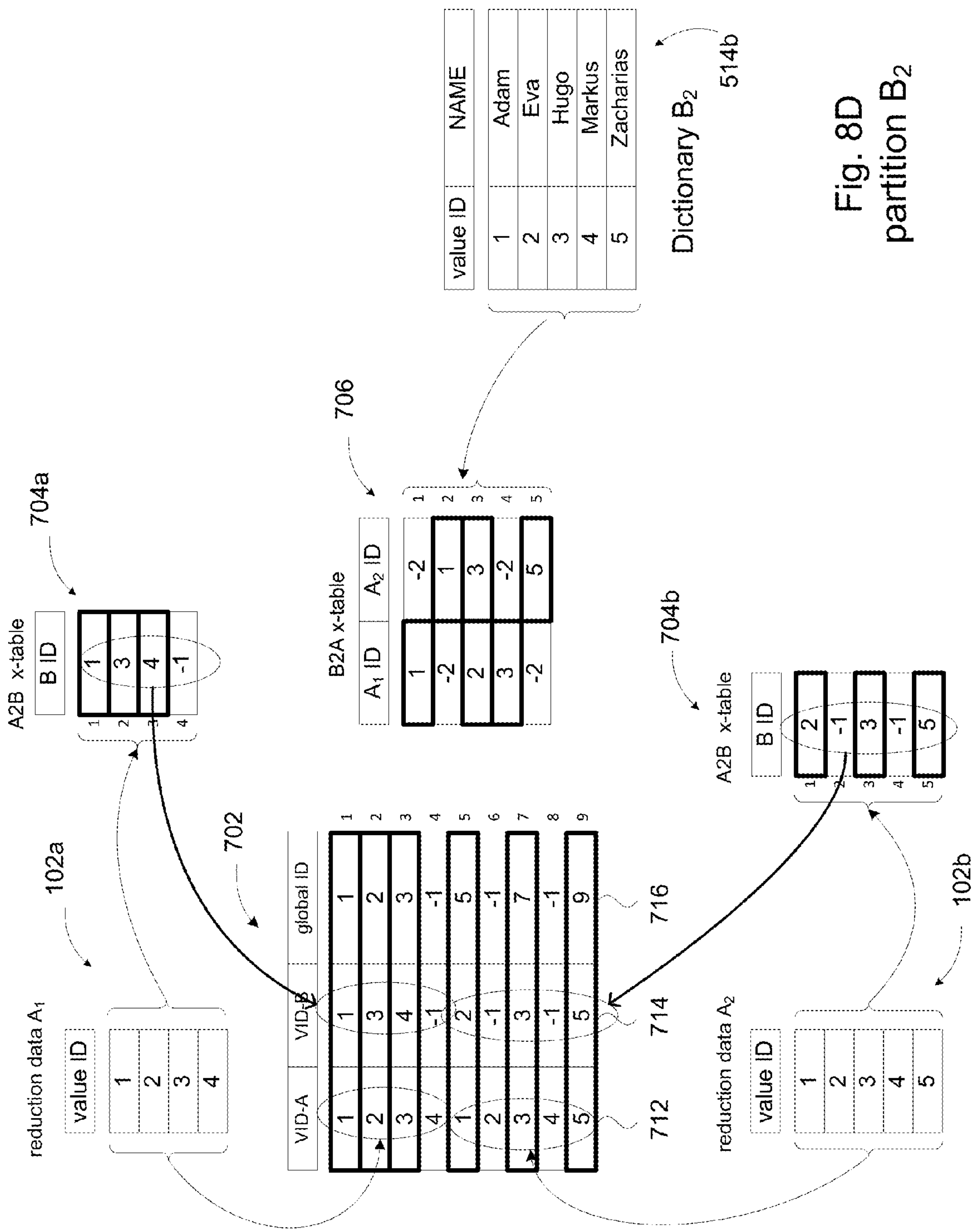


Fig. 8D
partition B_2

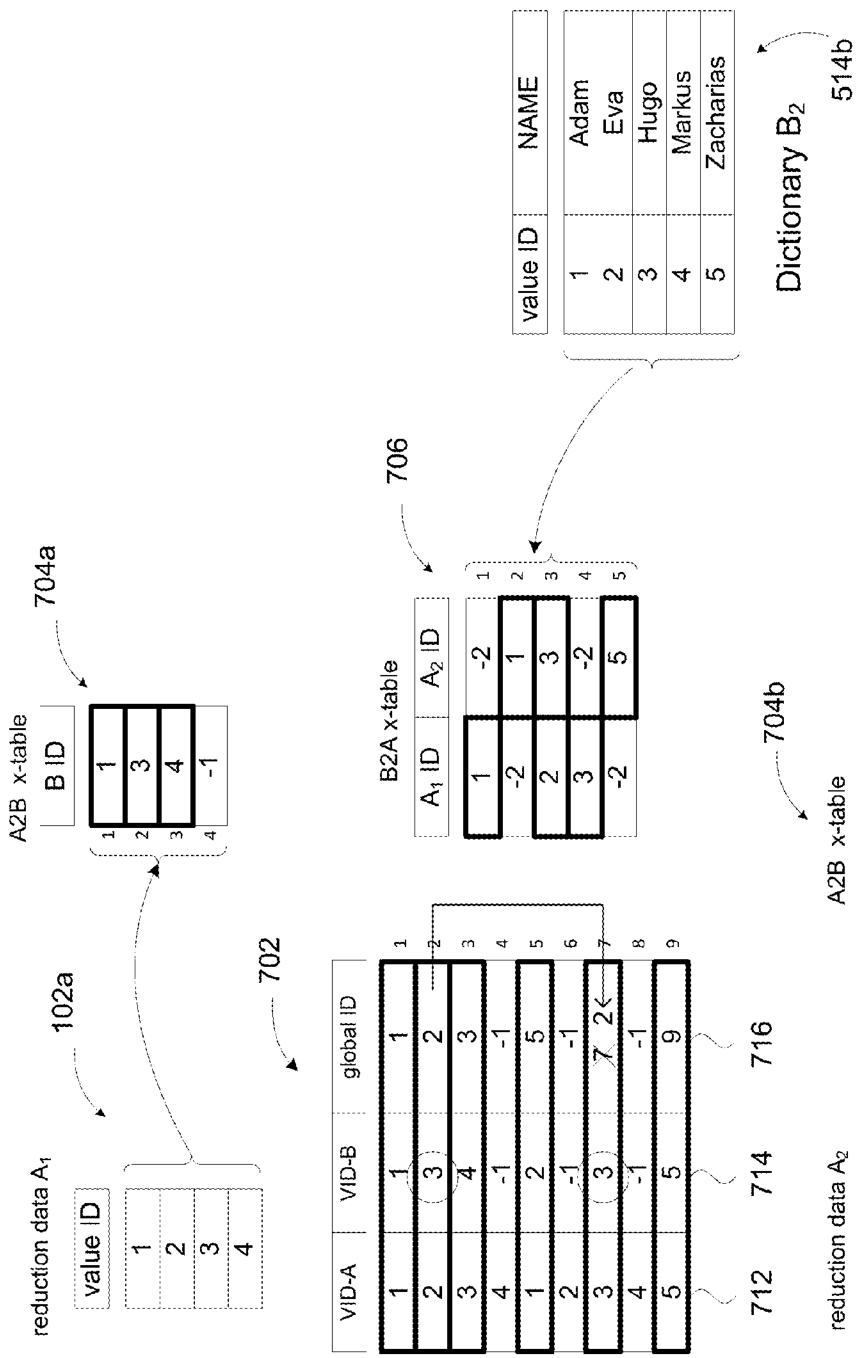


Fig. 8E
partition B_2

702

translation matrix of partition B_1

702

translation matrix of partition B_2

VID-A	VID-B	global ID		VID-A	VID-B	global ID
1	2	1	Adam	1	1	1
2	-1	-1	Hugo	2	3	2
3	-1	-1	Markus	3	4	3
4	-1	-1		4	-1	-1
1	3	5	Eva	1	2	5
2	-1	-1		2	-1	-1
3	-1	-1	Hugo	3	3	2
4	-1	-1		4	-1	-1
5	4	9	Zacharias	5	5	9
712	714	716		712	714	716

B_1 partition

B_2 partition

Fig. 9

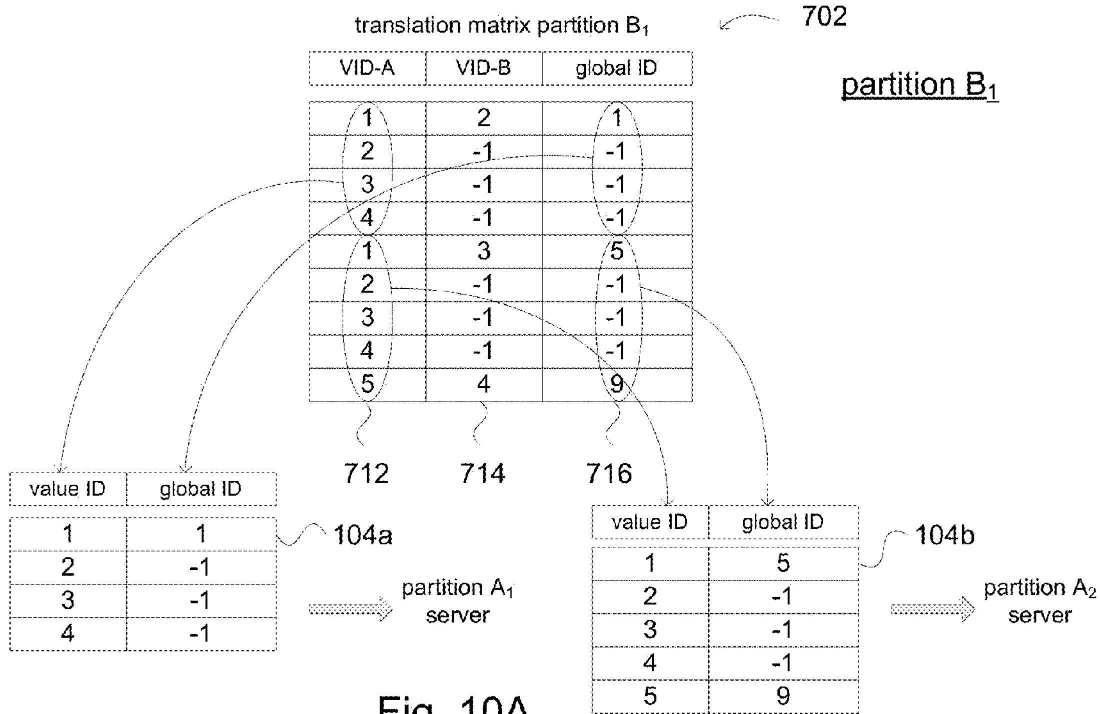


Fig. 10A

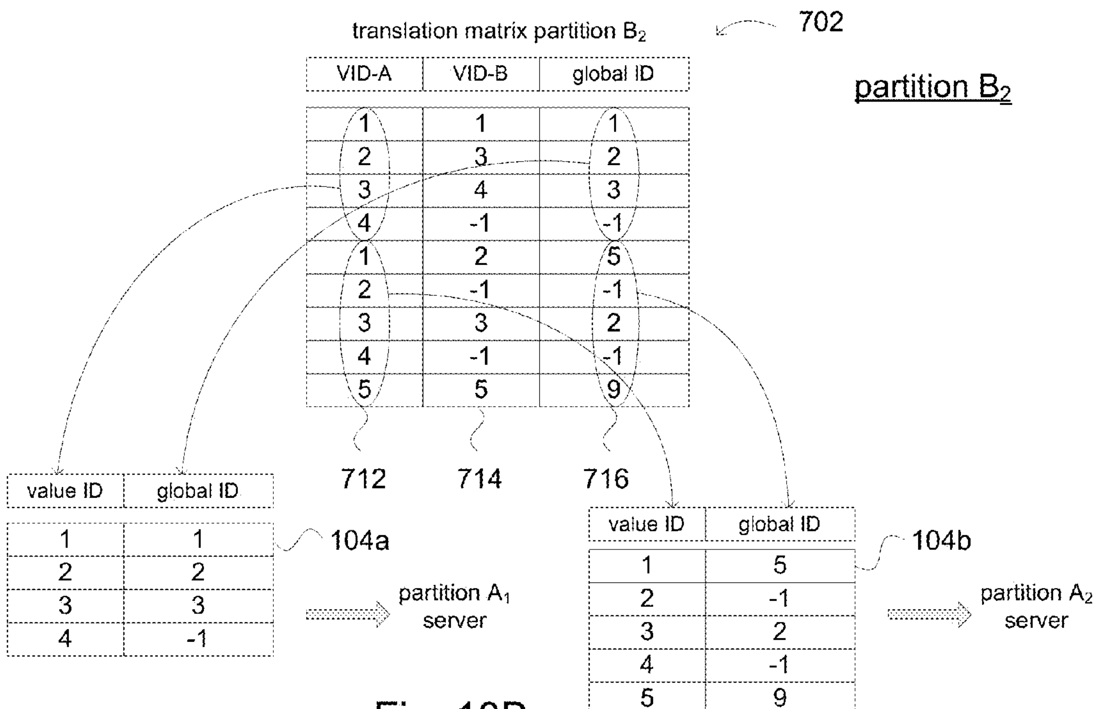


Fig. 10B

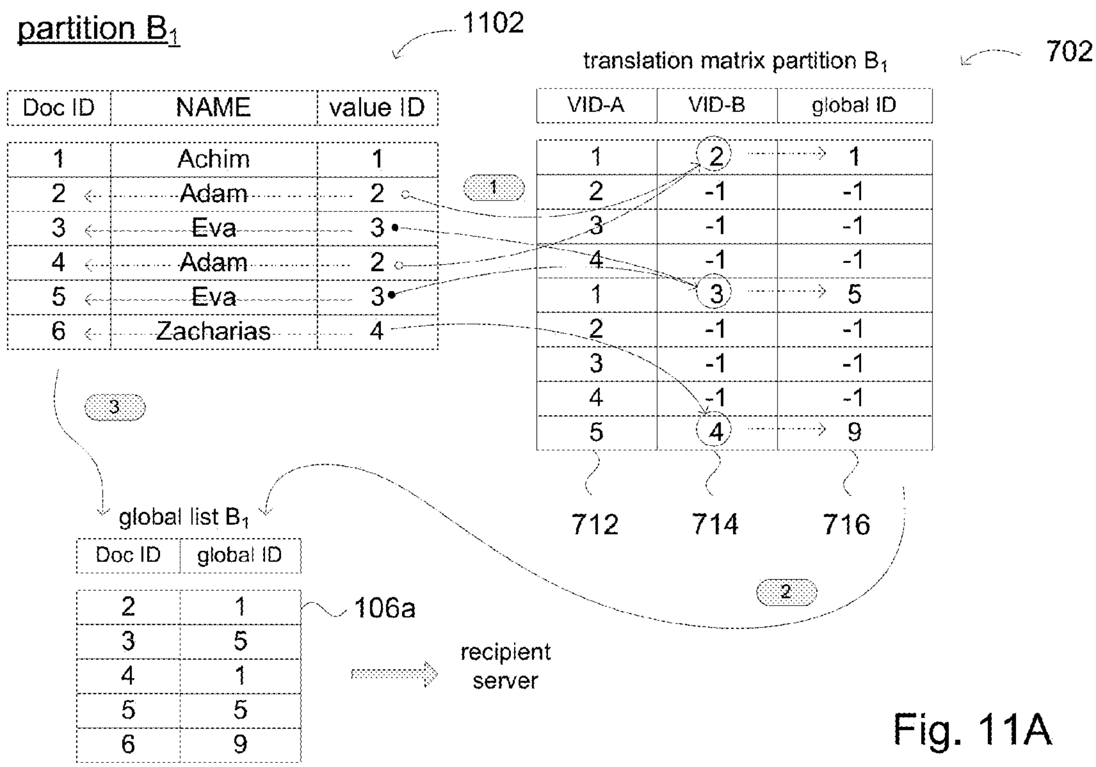


Fig. 11A

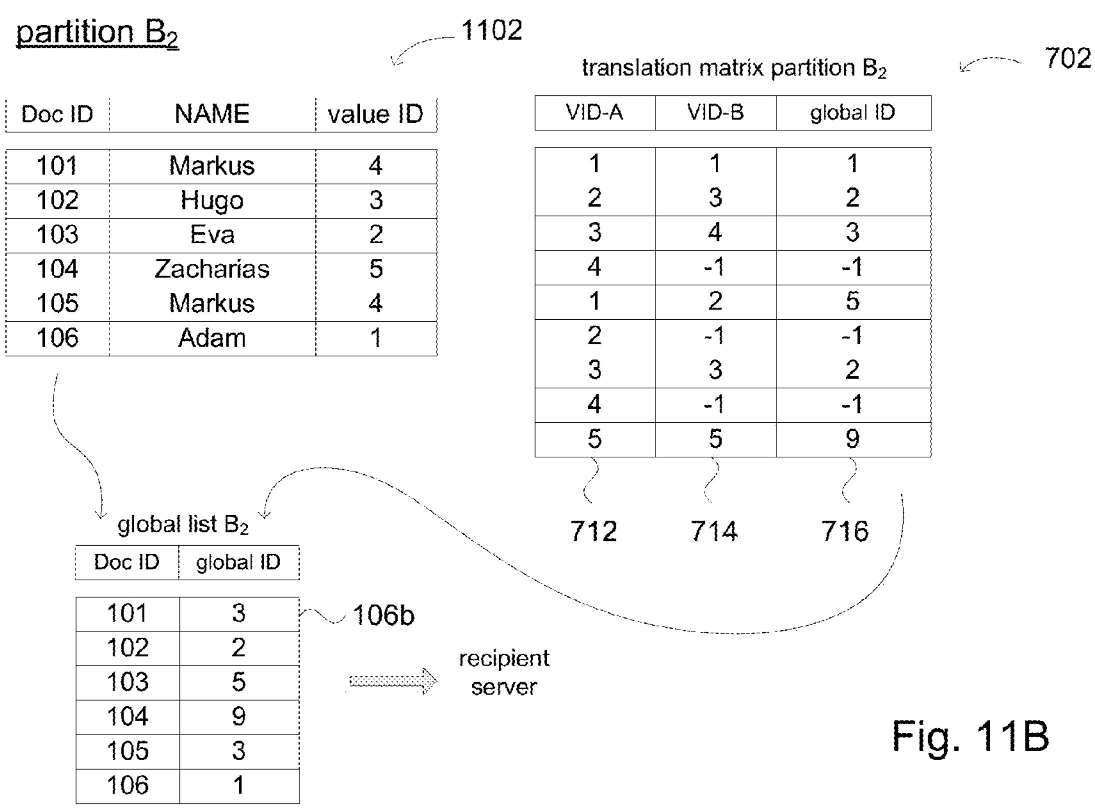


Fig. 11B

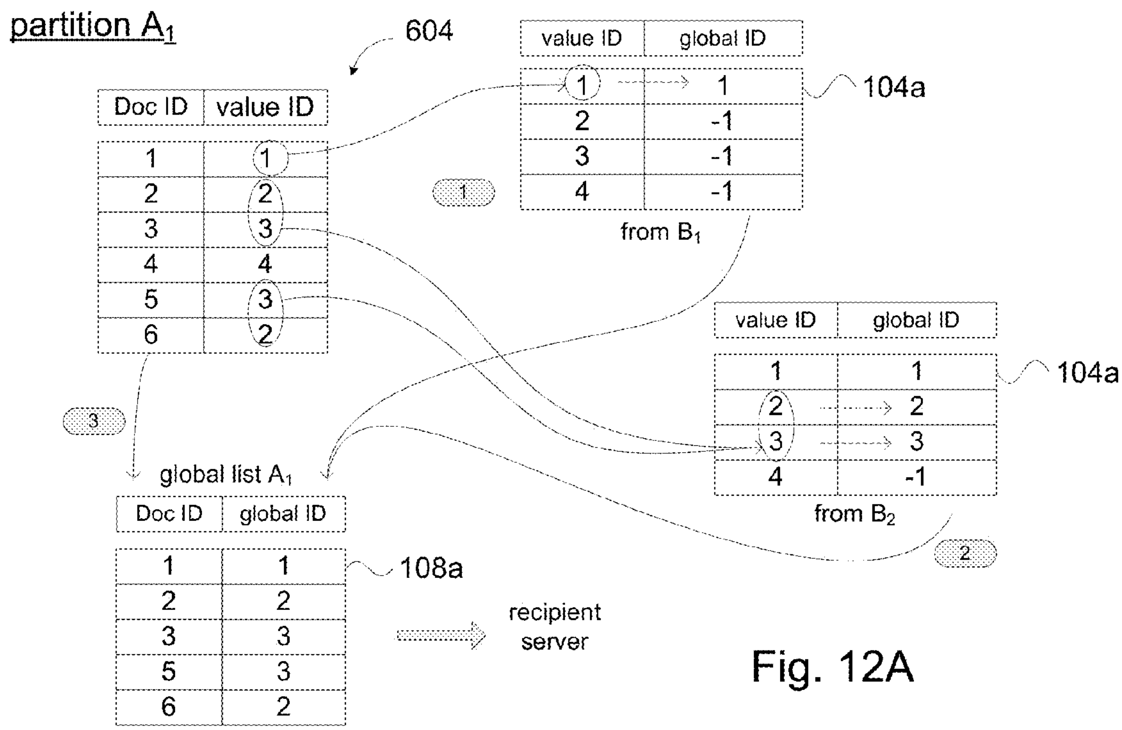


Fig. 12A

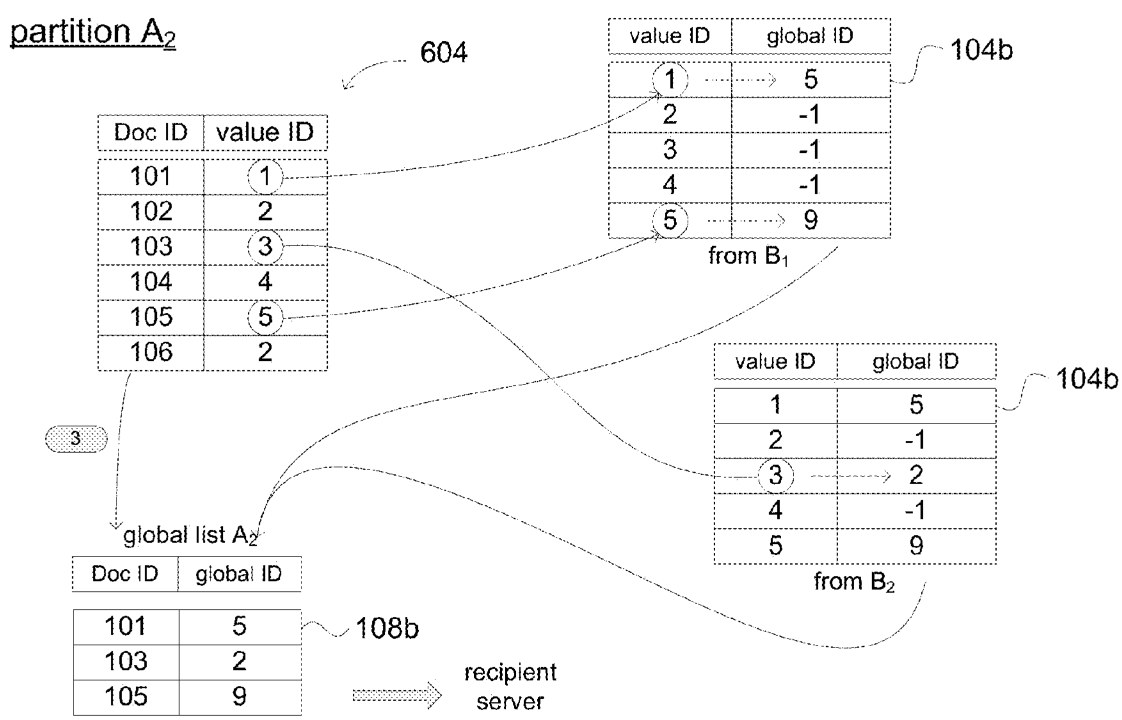
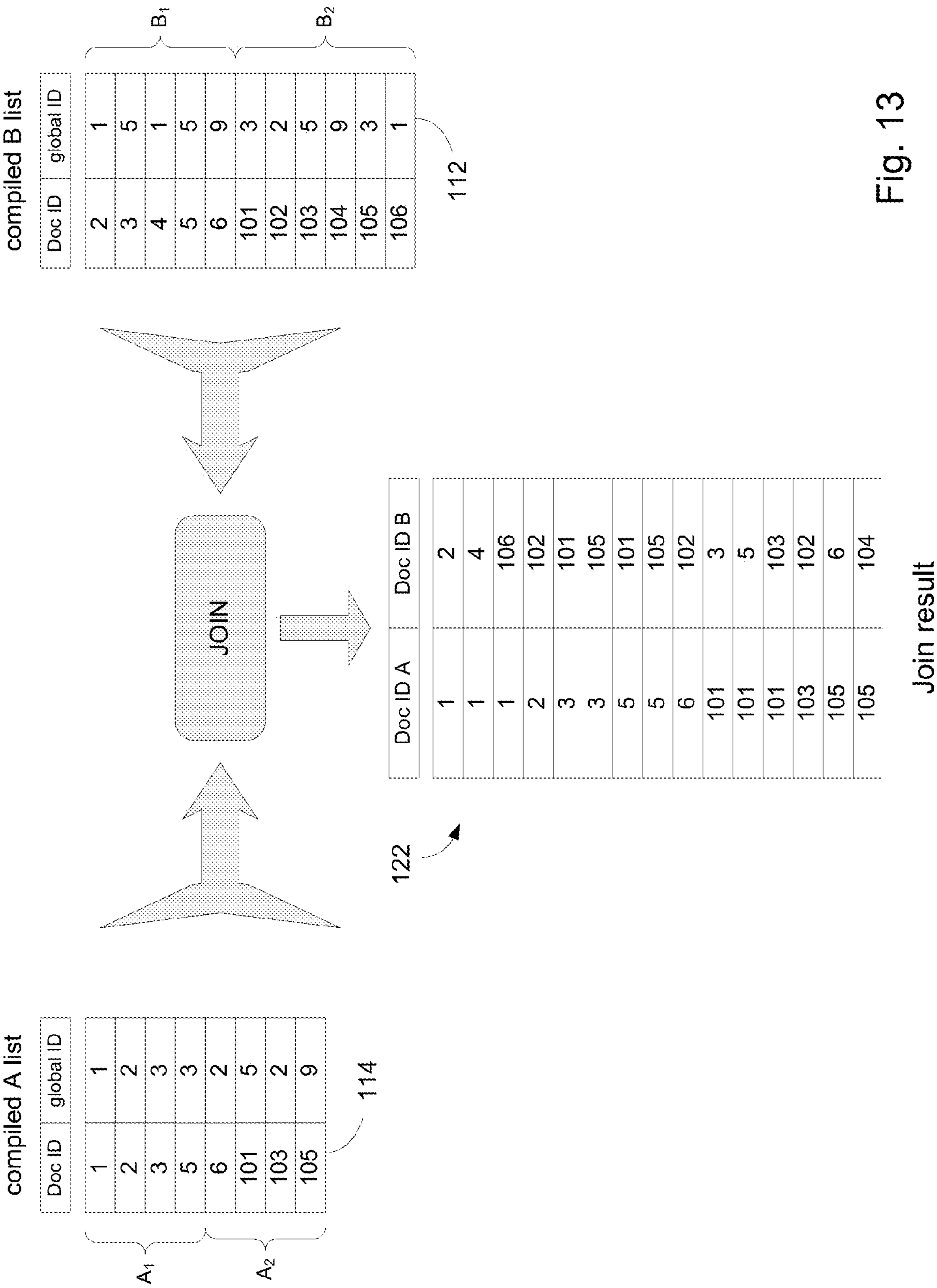


Fig. 12B



compiled A list

Doc ID	global ID
1	1
2	2
3	3
5	3
6	2
101	5
103	2
105	9

compiled B list

Doc ID	global ID
2	1
3	5
4	1
5	5
6	9
101	3
102	2
103	5
104	9
105	3
106	1

Join result

Doc ID A	Doc ID B
1	2
1	4
1	106
2	102
3	101
3	105
5	101
5	105
6	102
101	3
101	5
101	103
103	102
105	6
105	104

Fig. 13

Inventory Table

ID	Item	Quantity	Location
1	pants	200	1st floor
2	shirts	300	1st floor
3	toasters	50	2nd floor
4	lamps	75	3rd floor

1402

1406 1404a 1404b 1404c

Fig. 14A

Mail-Order Table

ID	Item	Sale Date	Quantity
1	shirts	4/1/2009	2
2	lamps	6/23/2008	5
3	lamps	2/27/2011	1

Fig. 14B

ID	Item	Quantity	Location	ID	Sale Date	Quantity
2	shirts	300	1st floor	1	4/1/2009	2
4	lamps	75	3rd floor	2	6/23/2008	5
4	lamps	75	3rd floor	3	2/27/2011	1

Fig. 14C

Inventory Table

ID	Item	Quantity	Location
1	2	200	1st floor
2	3	300	1st floor
3	4	50	2nd floor
4	1	75	3rd floor

Mail-Order Table

ID	Item	Sale Date	Quantity
1	3	4/1/2009	2
2	1	6/23/2008	5
3	1	2/27/2011	1

dictionary

actual value	value ID
lamps	1
pants	2
shirts	3
toasters	4

Fig. 15

EQUI-JOINS BETWEEN SPLIT TABLES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application and pursuant to 35 U.S.C. §120 is entitled to and claims the benefit of earlier filed application U.S. application Ser. No. 13/117,894 filed May 27, 2011, now U.S. Pat. No. 8,793,287, the content of which is incorporated herein by reference in its entirety for all purposes.

BACKGROUND

The present invention relates to database operations, and in particular to equi-join operations among split tables.

Unless otherwise indicated herein, the approaches described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

A common database operation in a relational database is the join operation. Generally, a join of two data sources creates an association of objects in one data source with objects that share a common attribute in another data source. A typical data structure for data sources is a data table (or simply, table) comprising rows and columns Each row (or record) of the data table represents an object. Each column represents attributes of the object. For example, a data table may be defined for inventory in a retail store. The inventory items (e.g., pants, shirts, toasters, lamps, etc.) may constitute the objects represented by the data table. The attributes of each item may include such information as the name of the item, the number of items at that store, the location of the item in the store, and so on. Instances of an attribute are referred to as "attribute values", "actual values", or simply "values." An example of such a data table is shown in FIG. **14**A, where each row **1402** represents a store item. Each row **1402** comprises attributes of the item columns **1404***a*-**1404***c*. Each row **1402** may include an ID attribute **106** that identifies the row. For example, the ordinal position of a row **1402** in the data table may be used as the ID attribute.

FIG. **14**B shows an example of another data table called Mail-Order. A join operation between the Inventory and Mail Order data tables can be performed. For example, consider a so-called "equi join" type of join operation where the join condition (join predicate) specifies a relationship (e.g., equality) between attributes that are common to both data tables. Suppose the join condition is: items in the Inventory data table that are the same as the items in the Mail-Order data table. For example, the join expression might be formulated as "Table Inventory inner join Table MailOrder on Inventory.Item=Mail-Order.Item".

An execution plan (query plan) for performing the join operation may include the following steps:

1. read out a row from the Inventory table
2. compare the actual value of the Item attribute in the row that was read out from the Inventory table with the actual value of the Item attribute in a row of the Mail-Order table
3. if there is a match, then output the row that was read out from the Inventory table and the matching row in the Mail-Order table
4. repeat steps 2 and 3 for each row in the Mail-Order table
5. repeat steps 1-4 for each row in the Inventory table

A result of the join operation can be represented by the data table shown in FIG. **14**C.

A database may comprise data tables that contain thousands of records each. In addition, records may have tens to hundreds of attributes each, and the actual values of some attributes may be lengthy (e.g., an attribute that represents the name of a person may require an allocation of 10-20 characters of storage space). Such databases can impose heavy requirements in the storage of their data. Accordingly, a practice of using dictionaries has arisen, where the actual values (e.g., 10-20 characters in length) of instances of an attribute in the data table are replaced by (or otherwise mapped to) an associated "value ID" (e.g., two or three bytes in length).

Consider the Inventory table and the Mail-Order table, for example. The actual values for instances of the Item attribute in the Inventory table include "pants", "shirts", "toasters", and "lamps". A dictionary can be defined for the Item attribute. For example, the dictionary may store the actual values of the Item attribute in alphabetical order and the value IDs that are associated with the actual values might be the ordinal position of the actual values in the dictionary.

An actual value in the data table is represented only once in the dictionary. For example, the actual value "lamps" occurs in twice in the Mail-Order table, but there is only one entry in the dictionary; thus, the dictionary might look like:

lamps
pants
shirts
toasters

The value ID associated with the actual value "lamps" could be 1, being located in the first position in the dictionary. The value ID associated with the actual value "pants" could be 2, being the second position in the dictionary, and so on.

FIG. **15** shows the Inventory and Mail-Order tables of FIGS. **14**A and **14**B, modified by the use of a dictionary, more specifically a central dictionary. In particular, the actual values for instances of the Item attribute in the data tables (i.e., text) have been replaced by their corresponding associated value IDs (i.e., an integer). It can be appreciated that the use of dictionaries can reduce the storage burden of large databases.

The distribution of databases across separate database servers is commonly employed, for example, to distribute the storage burden across multiple sites. In a distributed database configuration, one or more constituent data tables of the database are partitioned (split) into some number of "partitions," and the partitions are distributed across many database servers. While the processing of certain queries in a distributed database configuration may be accomplished using only the data within a given partition of a data table, queries that involve a join operation require access to data from all of the partitions of the data tables being joined.

The execution plan of a join operation involving split (partitioned) data tables conventionally involves communicating the actual values of the attribute(s) specified in the join condition among the partitions in order to evaluate the join condition. One can appreciate that the execution plan may therefore entail a significant amount of data communication among the constituent partitions. As explained above, a dictionary can be used to reduce the space requirements for storing attribute values. Accordingly, each partition may be provided with its own local dictionary (rather than the central dictionary indicated in FIG. **15**), the idea being that the associated value IDs can then be communicated among the partitions instead of the actual values. However, the value IDs in a given local dictionary are generated independently of the values IDs in the other local dictionaries. In other words, value IDs locally generated in one partition of a data table may have no correlation to value IDs locally generated in another partition of that data table. Suppose, for example, the Item attribute is specified in a join condition. Suppose further that the actual value "pants" has a value ID of 2 in the local dictionary of one partition, a value ID of 7 in the local dictionary of another partition, and a value ID of 15 in yet another partition. The execution plan for the join operation may communicate the multiple different value IDs for "pants" (i.e., 2, 7, 15) among the partitions. However, the value IDs would be meaningless in any one partition for the join operation because value IDs only have meaning for the partition in which they were generated. For example, while the value ID 2 may be associated with "pants" in one partition, the value IDs 7 and 15 do not, and in fact very likely may be associated with completely different items; the value IDs could not be used to perform a join operation.

These and other issues are addressed by embodiments of the present invention, individually and collectively.

SUMMARY

In embodiments, a join operation between a first split data table and a second split data table includes receiving reduction data from each of first partitions of the first data table. In a second partition, actual values of a join attribute that occurs in the second partition which also occur in one of the first partitions is assigned a global ID. A globalized list for the second partition includes a Doc ID that identifies a data record in the second partition for which the actual value of the join attribute also occurs in one of the first partitions. The corresponding global ID is associated with that actual value. Each first partition receives a table of global IDs that are associated with actual values in the first partition. Each first partition creates a globalized list that includes a Doc ID identifying data records in the first partition for which the actual value of the join attribute is identified by a global ID in the received table. The join operation can then be performed using the globalized lists of the first partitions and the globalized lists of the second partitions.

In an embodiment, a computer system can have stored therein executable program code configured to cause the computer system to perform the foregoing steps.

In embodiments, the same global ID may be associated with an actual value that occurs in the second partition and in at least one or more of the first partitions.

In embodiments, multiple occurrences of an actual value in the second partition are associated with the same global ID.

The following detailed description and accompanying drawings provide a better understanding of the nature and advantages of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** represents a high level flow of data among database table partitions to conduct a join operation in accordance with principles of the present invention.

FIG. **1**A show a general example of some details in a partition.

FIG. **2** illustrates a system diagram that can incorporate embodiments of the present invention.

FIGS. **3** and **3**A are process flows for processing among partitions in accordance with principles of the present invention.

FIG. **4** illustrates an example of data tables to facilitate an explanation of aspects of embodiments of the present invention.

FIG. **4**A illustrates a join operation in a non-distributed configuration of the data tables of FIG. **4**.

FIGS. **5** and **5**A illustrate the data tables of FIG. **4** in a split and distributed configuration.

FIG. **6** illustrates some processing in each A partition.

FIGS. **7** and **7**A-**7**D illustrate data manipulations for a join operation in accordance with principles of the present invention, in one of the B partitions.

FIGS. **8** and **8**A-**8**E illustrate data manipulations for a join operation in accordance with principles of the present invention, in another of the B partitions.

FIG. **9** compares the results of translation matrices from each B partition.

FIGS. **10**A and **10**B illustrate generating value ID lists in accordance with embodiments of the present invention.

FIGS. **11**A-**12**B illustrate generating globalized lists.

FIG. **13** shows a final step in the join operation of split data tables.

FIGS. **14**A-**14**C and **15** illustrate some basic principles and examples of data tables.

DETAILED DESCRIPTION

In the following description, for purposes of explanation, numerous examples and specific details are set forth in order to provide a thorough understanding of the present invention. It will be evident, however, to one skilled in the art that the present invention as defined by the claims may include some or all of the features in these examples alone or in combination with other features described below, and may further include modifications and equivalents of the features and concepts described herein.

Aspects of the present invention relate to performing a join operation between two distributed data tables. In particular, an equi-join operation may be performed between data tables that are split into multiple distributed partitions. FIG. **1** is a high level view of an illustrative embodiment of the present invention. Partitions A_1-A_n constitute N partitions of a data table A and can be distributed among some number (<=N) of data severs. For example, suppose data table A having 1000 rows (records) of data is split into four distributed partitions; partition A_1 might store a portion of the data table such as rows 1-200, partition A_2 might store rows 201-477 of the data table, partition A_3 might store rows 478-756, and partition A_4 might store rows 757-1000. Partitions B_1-B_m similarly constitute M partitions of a split data table B that can be distributed among some number (<=M) of data servers. In accordance with embodiments, there are no restrictions relating to the distribution of partitions A_1-A_n and B_1-B_m among data servers (e.g., a data server may host partitions from data table A and from data table B), or to the number of data servers that are configured for hosting the partitions.

Referring to FIG. **2** for a moment, a typical computer system configuration in accordance with embodiments of the present invention is shown. In embodiments, a plurality of servers **210**, **215**, and **231**-**235** may host or otherwise store and maintain distributed partitions for one or more split data tables. For example, partition A_1 might be stored in server **210**, partition A_2 might be stored in server **231**, partition B_1 might be stored in server **234**, and so on. For convenience, it is noted that the term "partition" can be used in several related contexts. The term "partition" may refer to the data that constitute a given portion of a data table, or to components of the storage system containing such data. The term "partition" may also refer generally to the server that is hosting the given portion of the data table, or to software employed to manipulate, maintain, and otherwise manage the data that constitute the given portion of the data table. It will be appreciated that the specific meaning of the term "partition" can be inferred from its usage and context.

Communication networks can connect the servers **210**, **215**, and **231**-**235**. For example, a local network **220** may connect servers **210**, **215**. A publicly accessed network (e.g., the Internet) **230** may connect server **231**-**235**. The local network **220** may be connected to the publicly accessed network **230**, allowing communication among the database servers **210**, **215**, and **231**-**235**.

Each server (e.g., **210**) may include a data processor subsystem **201** that may comprise one or more data processing units. A memory subsystem **202** may comprise random access memory (usually volatile memory such as DRAM) and non-volatile memory such as FLASH memory, ROM, and so on. The memory subsystem **202** may store computer executable programs, which when executed can cause the data processing subsystem **201** to operate as a database system in accordance with aspects of the present invention disclosed herein. A storage subsystem **203** may comprise one or more mass storage devices such as hard disk drives and the like. The storage subsystem **203** may include remote storage systems; e.g., for data mirroring, remote backup and such. A network interface subsystem **204** can provide access to the local network **220** and provide users with access to the server **210**. A system of buses **205** can interconnect the foregoing subsystems, providing control lines, data lines, and/or voltage supply lines to/from the various subsystems. The server **210** may include a suitable display(s) **212** and input devices **211** such as a keyboard and a mouse input device.

FIGS. **1** and **3** represent a high level flow of an execution plan for performing a join operation of two data tables A and B that are split and distributed, in accordance with aspects of the present invention. The join operation is predicated on a join condition that specifies an attribute(s) common to the two data tables A and B, which will be referred to as the "specified attribute". For example, consider an Inventory data table and a Sales data table; an attribute in the Inventory data table might be Stocked_Items and an attribute in the Sales data table might be Purchased_Items. A join operation between these two data tables might specify a join condition such as "Inventory.Stocked_Items=Sales.Purchased_Items". The Stocked_Items attribute would be the "specified attribute" in the Inventory data table, and the Purchased_Items attribute would be the "specified attribute" in the Sales data table.

In embodiments, the two data tables A and B may be split into respective partitions A_1-A_n and B_1-B_m. Referring for a moment to FIG. **1**A, a generalized example of a data table partition is shown. The partition comprises n rows taken from a larger data table. Each row stored in the partition comprises m attributes. The partition may include one or more dictionaries, each corresponding to an attribute. For example, FIG. **1**A shows that a dictionary is defined for attribute 1 and another dictionary is defined for attribute 2. The value IDs for attribute 1 and attribute 2, respectively, are stored in the partition rather than their associated actual values. As mentioned above, the dictionary(ies) in a given partition may be local to that partition. In other words, the value IDs stored in the dictionary(ies) of one partition may not correlate with the value IDs of dictionary(ies) of another partition, even though they may contain identical actual values.

Turning to the execution plan illustrated in FIG. **3**, a brief overview of processing a join operation involving split (partitioned) data tables will be given. Reference will be made to partitioned data tables A and B illustrated in FIG. **1**.

In a step **302**, each partition A_x among the partitions A_1-A_n generates reduction data **102** and sends a copy of the generated reduction data to each partition B_1-B_m. Accordingly, each partition B_1-B_m receives reduction data **102** from each partition A_1-A_n. In embodiments, the reduction data **102** for partition A_x comprises value IDs associated with actual values of instances of the specified attribute that occur in the partition. The step **302** can be performed by each partition A_x independently of the other partitions A_1-A_n; there is no need to synchronize or otherwise coordinate their activity. In other words, individual reduction data **102** from each partition A_1-A_n can be communicated to the partitions B_1-B_m in parallel fashion.

In a step **304**, each partition B_x among the partitions B_1-B_m associates a global ID for each actual value of the specified attribute in the partition that also occurs in at least one of the partitions A_1-A_n. In embodiments, the reduction data **102** received from the partitions A_1-A_n can be used to perform this step. Multiple occurrences of a given actual value in the partition B_x will be associated with the same global ID. In accordance with the present invention, occurrences of a given actual value among all the partitions of data table A and data table B can be associated with the same global ID. This aspect of the present invention will be discussed in more detail in connection with a specific example discussed below.

In a step **306**, each partition B_x among the partitions B_1-B_m translates the value IDs that comprise the reduction data **102** from each partition A_1-A_n, producing a set of translated value IDs **104** for each partition A_1-A_n. Consider a partition A_x, for example. Translated value IDs **104** for partition A_x are generated from the value IDs that comprise the reduction data **102** received from that partition. In particular, each value ID in the reduction data **102** is first associated with an actual value stored in the partition A. Next, if that actual value also occurs in the partition B_x, then the value ID is "translated" by pairing it with the global ID that is associated with that actual value. This translation is attempted for each value ID in the reduction data **102** of partition A. Accordingly, the translated value IDs **104** will comprise one or more values IDs that are paired with respective global IDs. Some value IDs in the reduction data **102** may be associated with actual values which do not occur in the partition B_x and so no translation is made. The translated value IDs **104** are then sent to the partition A_x (backward communication). This step is performed for each of the partitions A_1-A_x, and by each partition B_1-B_m. This aspect of the present invention will be discussed in more detail below.

In a step **308**, each partition B_x among the partitions B_1-B_m generates a globalized list **106** that identifies one or more rows stored in the partition. Each row that is identified in the globalized list **106** contains an actual value of the specified attribute which also occurs in one of the partitions A_1-A_N (based on the reduction data **102** as explained above). In an embodiment, the globalized list **106** may include a 2-tuple (a data pair) comprising a Doc ID and a global ID. The Doc IDs in the 2-tuples of the globalized list **106** identify specific rows in the partition B_x for which the actual values of the specified attribute also occur in one of the partitions A_1-A_n. The global IDs in the 2-tuples are associated with those actual values. As a side note, the term "Doc ID" will be used herein to refer to an identifier that identifies a particular row in a data table. This aspect of the present invention will be made more clear in the specific example discussed below.

In embodiments, the globalized list **106** can be sent to a receiving (recipient) data server. For example, any data server **210**, **215**, **231**-**235** can be designated as the recipient data server. The recipient data server can be selected from among a population of candidate data servers in round-robin fashion, or selected randomly. In an embodiment, a particular data server can be designated as always being the recipient data server rather than employing a round robin selection process.

In a step **310**, each partition A_x among the partitions A_1-A_n generates a globalized list **108** based on the translated value IDs **104** received from each of the partitions B_1-B_m. The globalized list **108** identifies one or more rows stored in the partition A. In an embodiment, the globalized list **108** includes a 2-tuple (a data pair) for each identified row. Each 2-tuple in turn comprises a Doc ID and a global ID. The Doc IDs identify one or more rows of the partition A. The global IDs are obtained from the translated value IDs **104** received from partitions B_1-B_m. In embodiments, the globalized list **108** identifies rows in partition A_x for which actual values (represented by the global IDs) of the specified attribute also occur in one of the partitions B_1-B_m. This aspect of the present invention will be discussed in more detail below. The globalized list **108** can be sent to a recipient data server. In an embodiment, the recipient data server can be the same data server employed to receive globalized lists **106** from partitions B_1-B_m. In an embodiment, a different data server can be employed.

In a step **312**, when the recipient data server has received all of the globalized lists **106** from partitions B_1-B_m, a compiled B list **112** can be created. The compiled B list **112** comprises pairs of Doc IDs and global IDs, and identifies those rows among partitions B_1-B_m for which the actual values of the specified attribute also occur in at least one of the partitions A_1-A_n. Similarly, when the recipient data server has received all of the globalized lists **108** from partitions A_1-A_n, a compiled A list **114** can be created. The compiled A list **114** comprises pairs of Doc IDs and global IDs, and identifies those rows among partitions A_1-A_n for which the actual values of the specified attribute also occur in at least one of the partitions B_1-B_m.

In a step **314**, a join operation is performed between the compiled A list **114** and the compiled B list **112**, where the join condition is based on the global ID attribute that is common to the compiled A list and the compiled B list. Since the global IDs are associated with actual values of the specified attribute, the join operation performed in this step is equivalent to the desired join operation between the specified attributes.

Following will be a more detailed discussion of the foregoing processing steps shown in FIG. **3**, explained in connection with a particular example to facilitate further understanding of aspects of the present invention. Consider first the case of a join operation for non-partitioned data tables.

FIG. **4** shows two data tables, data table A **402** and data table B **404**. Data table A specifies X attributes, where the first attribute is a Doc ID attribute and the second attribute is a Name attribute. Similarly, data table B specifies Y attributes also including a Doc ID attribute and a Name attribute. The Doc ID attribute identifies each row in a respective data table and so its actual values can be arbitrarily assigned so long as they serve to uniquely identify each row in that data table. Each data table A, B may have one or more dictionaries defined on their attributes in order to reduce data storage requirements.

Suppose a join operation is performed on the data tables A and B, predicated on the Name attribute in data table A being equal to the Name attribute in data table B. An execution plan for the join operation may involve generating an index on the Name attribute for each data table A and B. For example, FIG. **4**A shows Index A **414** and Index B **412**, represented as tables comprising the Doc ID attribute and the Name attribute. The figure shows a result **422** of the join operation, which is a table comprising a Doc ID A attribute and a Doc ID B attribute. The

Doc IDs identify respective rows in data tables A and B that have the same actual values in their Name attribute.

Referring to FIGS. **5** and **5**A, consider an example of the split configurations of the data tables A and B shown in FIG. **4**. FIG. **5** shows data table A having been partitioned into partitions A_1, A_2 (**502***a*, **502***b*) and data table B being partitioned into partitions B_1, B_2 (**504***a*, **504***b*). FIG. **5**A shows dictionaries **512***a*, **512**, *b*, **514***a*, **514***b* for the Name attribute in each respective partition A_1, A_2, B_1, and B_2, one dictionary being defined for each partition. Each occurrence of an actual value of the Name attribute in a partition has an entry in its respective dictionary and is associated with a value ID. Note that the value IDs among the dictionaries are not related. For example, value ID 2 in dictionary A_1 is associated with the actual value "Hugo", while the same value ID in dictionary A_2 is associated with the actual value "Herbert". FIG. **5** shows the value IDs associated with the actual values of the Name attribute for each partition A_1, A_2, B_1, and B_2, obtained from the dictionaries of FIG. **5**A. Though the value IDs in a given dictionary can be arbitrarily selected (so long as they uniquely identify an actual value and the actual value is uniquely identified by the value ID), embodiments of the present invention may adopt the convention that the value IDs be the ordinal positions in the dictionary of their corresponding actual values. Accordingly, the value IDs are consecutive, beginning with "1".

Consider now the join operation discussed above in connection with FIG. **4**, namely a join operation of the split data tables A and B of FIG. **5** predicated on the Name attribute in data table A being equal to the Name attribute in data table B (the join condition). The execution plan shown in FIG. **3** for conducting a join operation in accordance with the present invention will now be explained in the context of the specific example illustrated in FIGS. **5** and **5**A. For the discussion that follows, references to "actual value" will be understood to refer to actual values of the Name attribute (the specified attribute) in data table A or in data table B.

Step **302**—Generate and Send Reduction Data

Referring to FIG. **6**, each partition A_1, A_2 generates and sends respective reduction data **102***a*, **102***b* to partitions B_1, B_2. The reduction data **102***a*, **102***b* can be obtained from the local dictionary of the respective partition. For example, the reduction data **102***a* from partition A_1 is communicated to each partition B_1, B_2. Likewise, the reduction data **102***a* from partition A_2 is communicated to each partition B_1, B_2. In a particular embodiment, an index table **602** can be created in each partition A_1, A_2. Each index table **602** comprises the Doc ID attribute and the Name attribute obtained from the respective partition, and a value ID attribute obtained from the partition's local dictionary. A tuple list **604** comprising Doc IDs and initially populated with corresponding value IDs can be generated and stored in the respective partition. The significance of table **602** and list **604** will become clear later on.

Step **304**—Associate Global IDs

Each partition B_1, B_2 associates a global ID for each actual value of the Name attribute in the partition that also occurs in at least one of the partitions A_1, A_2. Referring to FIGS. **3**A, **7**, and **7**A-**7**D, consider first the processing in partition B_1. Processing in partition B_2 will be discussed in connection with FIGS. **8** and **8**A-**8**D.

In a step **322**, various tables can be created and initialized in partition B_1. In an embodiment, these tables are local to partition B_1. FIG. **7** shows the reduction data **102***a*, **102***b* received in partition B_1 from partitions A_1, A_2. In embodiments, the reduction data **102***a*, **102***b* may be incorporated into a translation matrix **702** local to partition B_1. The value IDs in the reduction data **102***a*, **102***b* may be assembled into a VID-A column **712**. A VID-B column **714** is initialized to "−1"; this column will be filled in with value IDs from the local dictionary of partition B_1.

The translation matrix **702** includes a global ID column **716** which is initialized with its corresponding ordinal position in the translation matrix. In general, any set of numbers can be used to initialize the global ID column **716** so long as each row has a unique number and the same set of numbers is used by each of the partitions B_1, B_2. Initially, the value IDs 1, 2, 3, and 4 from partition A_1 are initially mapped to global IDs 1, 2, 3, and 4 (namely rows 1-4 of the translation matrix **702**); and the value IDs 1, 2, 3, 4, and 5 from partition A_2 are initially mapped to global IDs 5, 6, 7, 8, and 9 (rows 5-9 of the translation matrix).

Additional tables are created and initialized. An A2B translation table is created for each partition A_x, and initialized to "−1". For example, partition A_1 has a corresponding A2B translation table **704***a* and partition A_2 has a corresponding A2B translation table **704***b*. The translation tables **704***a*, **704***b* serve to translate the value IDs from partitions A_1 and A_2 to corresponding value IDs in partition B_1. Since the respective value IDs for A_1, A_2 are consecutive by convention, the value IDs correspond directly with the row indices in tables **704***a*, **704***b*. For example, the value ID "3" for partition A_1 can be used to index into translation table **704***a* to obtain the translated value ID in partition B_1. This use of the indices is illustrated in FIG. **7**.

A B2A translation table is created and initialized with "−2". The partition B_1 has a corresponding B2A translation table **706** which includes a corresponding column for each partition A. The B2A translation table **706** serves to provide a translation of the value IDs in the local dictionary of partition B_1 to corresponding value IDs in partitions A_1, A_2. Since the value IDs are consecutive, the row in table **706** for a given value ID can be accessed using the value ID itself as an index into the table.

Continuing with FIG. **3**A and referring now to FIGS. **7**A-**7**C, the translation tables **704***a*, **704***b*, **706** can be filled in the following manner: Consider first FIG. **7**A and partition A_1. In a step **324***a*, the value IDs from the corresponding reduction data **102***a* are sent to and received by the server that hosts partition A_1. For example, FIG. **7**A shows the list of value IDs {1, 2, 3, 4} being sent to the server. The actual values corresponding to the list of value IDs are obtained from the local dictionary of partition A_1 (see FIG. **5**A) and are sent by and received from the server in a step **324***b*. For example, the list of actual values received is {Adam, Hugo, Markus, Werner}. In a step **324***c*, if an actual value received from partition A_1 matches an entry in the local dictionary for partition B_1, then the value ID from B_1's local dictionary is copied to the corresponding entry in the A2B translation table **704***a*. As explained above, the A_1 value IDs can be used to index into the table **704***a*. Conversely, in a step **324***d*, partition A_1's value ID for that matching actual value is copied into the B2A translation table **706** indexed by the value ID from B_1's local dictionary. FIG. **7**A is annotated with steps **324***a*-**324***d* to illustrate this process.

Steps **324***a*-**324***d* are performed **324** by each partition A. For example, FIG. **7**B shows steps **324***a*-**324***d* performed for partition A_2. Since each partition A_x operates independently of each other, they can perform these steps at the same time. FIG. **7**C shows the result after each of the partitions have completed steps **324***a*-**324***d*.

It can be appreciated from the foregoing that the "−1" values in the A2B translation tables **704***a*, **704***b* indicate that there is no translation of value IDs from the respective A_1, A_2, partitions to the B_1 partition. Consider translation table **704***a* for partition A_1, for example. The second entry corresponds to a value ID 2 in partition A_1, which in turn corresponds to the value "Hugo". Since the local dictionary for partition B_1 does not have an entry for "Hugo", the entry in table **704***a* remains unchanged, namely it is "−1".

It can be further appreciated that the "−2" values in the B2A translation table **706** indicates that the partition B_1 has not yet received the corresponding value from the respective the A_x partition. For example, consider the first entry in the A_1 ID column of the table **706**. This entry corresponds to the first entry in the local dictionary for partition B_1, which contains the value "Achim" Since the local dictionary for partition A_1 (see FIG. **5**A) does not include the value "Achim", partition B_1 did not receive such value from partition A_1, and so the entry in table **706** remains unchanged, namely it is "−2". Previously communicated values can be locally cached in the B2A translation table **706** for subsequent join operations, thus avoiding redundant communications. Thus, for subsequent join operations involving data table A, only those entries that have "−2" may need to be filled with actual values.

Continuing with FIGS. **3**A and **7**D, in a step **326** the A2B translation tables **704***a*, **704***b* are mapped into their respective entries in the VID-B column **714** of the translation matrix **702**. FIG. **7**D shows the result of such mapping, the values are copied from the translation tables **704***a*, **704***b* into column **714**. In this way, the global IDs in column **716** become associated with actual values via the value IDs in columns **712** and **714**. For example, the value ID of 1 from partition A_1 is associated with "Adam" and so the global ID "1" is associated with "Adam." Similarly, global ID "5" is associated with "Eva."

For entries in the tables **704***a*, **704***b* which have no translation to corresponding value IDs in partition B_1, the corresponding global IDs in column **716** are changed to "−1" to indicate this fact. Thus, for example, value IDs 2, 3, and 4 in partition A_1 have no corresponding value IDs in partition B_1, and so the global IDs in rows 2, 3, and 4 of the translation matrix **702** are set to "−1". Similarly, value IDs 2, 3, and 4 in partition A_2 have no corresponding value IDs in partition B_1, and so the global IDs in rows 6, 7, and 8 of the translation matrix **702** are set to "−1".

In a step **328**, any duplicate VID-B values in column **714** would be handled in the following manner: For each VID-B value in column **714** that occurs more than once, copy the global ID (column **716**) associated with the first occurrence of that VID-B value into the global ID column of each duplicated VID-B value. However, the translation matrix **702** shown in FIG. **7**D for partition B_1 does not have any duplicated VID-B values. For example, the values 2, 3, and 4 each occurs only once in column **714**, and so their corresponding global IDs remain unchanged, namely 1, 5, 9 respectively. This is not the case in partition B_2, and the processing of step **328** is illustrated below for partition B_2.

Refer now to FIGS. **3**A, **8**, and **8**A-**8**D for a brief discussion of the processing (step **304**) of partition B_2 in accordance with embodiments of the present invention. Thus, in a step **322**, various tables local to partition B_2 can be created and initialized in the partition. FIG. **8** shows the reduction data **102***a*, **102***b* received in partition B_2 from partitions A_1, A_2. In embodiments, the reduction data **102***a*, **102***b* may be incorporated into a translation matrix **702** that is local to partition B_2. The VID-A column **712**, VID-B column **714**, and global ID column **716** are initialized in the same manner as explained in FIG. **7** for partition B_1. Likewise, the additional tables **704***a*, **704***b*, and **706** are initialized in the same manner as described in FIG. **7** for partition B_1. The B2A translation table **706** for partition B_1 in FIG. **7** contains four entries because B_1's local dictionary has four items. However, since B_2's local dictionary has five items, the B2A translation table **706** in FIG. **8** has five entries.

Referring now to FIG. **8**A, processing of steps **324***a*-**324***d* between partition B_2 and A_1 is illustrated. The list of value IDs for partition A_1 is sent to the server hosting the A_1 partition (**324***a*). The list of values corresponding to the value IDs is received from the server (**324***b*). In step **324***c*, the received list of values {Adam, Hugo, Markus, Werner} is used to map the A_1 value IDs to the B_2 value IDs, thus filling in the A2B translation table **704***a* for A_1. In step **324***d*, a similar mapping is made to map the B_2 value IDs to the A_1 value IDs, thus filling in the A_1 ID column in the translation table **706** for partition B_2.

Referring to FIG. **8**B, the processing of steps **324***a*-**324***d* between partition B_2 and A_2 is illustrated. FIG. **8**C show shows the result upon completion of loop **324**. In step **326**, the A2B translation tables **704***a*, **704***b* are mapped into their respective entries in the VID-B column **714** of the translation matrix **702**. FIG. **8**D shows the result of such mapping, the values are copied from the translation tables **704***a*, **704***b* into column **714**.

In step **328**, duplicate VID-B values in column **714** of the translation matrix **702** for partition B_2 are handled in the following manner: For each VID-B value in column **714** that occurs more than once, copy the global ID (column **716**) associated with the first occurrence of that VID-B value into the global ID column of each duplicated VID-B value. Referring to FIG. **8**E, The VID-B value of "3" appears twice. The first occurrence is associated with the global ID "2". Accordingly, the global ID value "2" is copied into the global ID column of each duplicate occurrence of "3" in the VID-B column **714**.

This concludes the discussion of step **304** (FIG. **3**) for partitions B_1 and B_2. FIG. **9** shows the translation matrices **702** that are stored in each partition B_1, B_2 at this point. A few observations are worth mentioning. Processing in accordance with embodiments of the present invention in partitions B_1, B_2 occurs independently of each other; there is no synchronization of their data or other communications. The resulting translation matrix **702** in a given partition contains global IDs that identify actual values (of the specified attribute in the join operation) in the given partition which also occur in at least one of the partitions A_1, A_2. Consider for example the value "Hugo" in FIG. **9**. "Hugo" appears in partition B_1 and in partition A_1, so "Hugo" is assigned a global ID (in this case 3). On the other hand "Achim" in partition B_1 does not appear in either partition A_1 or A_2. Accordingly, none of the translation tables **702** have a translation for "Achim" The global IDs are unique among the translation tables **702** for a given actual value. For example, "Hugo" appears in partitions B_1 and B_2. The translation matrices **702** in each partition B_1, B_2 map "Hugo" to the same global ID, namely "2".

The discussion will now continue with an explanation of the remaining steps **306**-**312** of FIG. **3**.

Step **306**—Send Translated Value IDs

Each partition B_1, B_2 translates the value IDs that comprise the reduction data **102***a*, **102***b* from respective partitions A_1, A_2, producing a set of translated value IDs. Referring to FIG. **10**A, the processing of this step in partition B_1 is shown. In an embodiment, the translation matrix **702** for partition B_1 can provide the contents of a translated value ID table **104***a* for partition A_1 and a translated value ID table **104***b* for partition A_2. As can be seen, the translated value ID table **104***a* comprises rows 1-4 from columns **712** and **716** of the translation matrix **702**. Likewise, the translated value ID table **104***b* comprises rows 5-9 from columns **712** and **716** of the translation matrix **702**. The tables **104***a*, **104***b* provide a translation of value IDs from partitions A_1, A_2 to the global IDs. In accordance with step **306**, the tables **104***a*, **104***b* are communicated to and received by respective partitions A_1, A_2. The same process occurs in partition B_2, and is illustrated in FIG. **10**B. Accordingly, partition A_1 will receive a translation value ID table **104***a* from partition B_1 and from partition B_2. Similarly, partition A_2 will receive a translation value ID table **104***b* from partition B_1 and from partition B_2.

Step **308**—Generate Global B Lists

Each partition B_1, B_2 generates a globalized list that identifies one or more rows stored in the partition. Each row that is identified in the globalized list contains an actual value of the specified attribute which also occurs in one of the partitions A_1, A_2. Referring to FIG. **11**A, processing of this step in partition B_1 is shown. In an embodiment, an index table **1102** can be created for partition B_1, comprising the Doc ID attribute and the Name attribute obtained from the partition, and a value ID attribute obtained from B_1's local dictionary.

In an embodiment, for each row in the index table **1102**: (1) if the value ID appears in column **714** of the translation matrix **702**, then (2) copy the corresponding global ID from column **716** into a globalized list **106***a* for partition B_1, and (3) copy the corresponding Doc ID from the index table for all instances of the value ID. For example, value ID 2 appears in column **714** of the translation matrix **702**. Two instances of the value ID 2 appear in the index table **1102**, and the corresponding Doc IDs are 2 and 4. Accordingly, 2 and 4 are recorded in the globalized list **106***a*. The global ID corresponding to value ID 2 is 1, and so 1 is recorded in the globalized list **106***a* next to Doc IDs 2 and 4. This is repeated for value IDs 3 and 4, which also appear in column **714** of the translation matrix **702**. The completed globalized list **106***a* can then be communicated to a recipient server.

Referring to FIG. **11**B, the foregoing is repeated for partition B_2: An index table **1102** is created from partition B_2. A globalized list **106***b* is then generated based on the index table and on the translation matrix **702** developed in partition B_2. The globalized list **106***b* is then communicated to the recipient server.

Step **310**—Generate Global A Lists

Referring now to FIGS. **12**A and **12**B, each partition A_1, A_2 can generate a globalized list using the tupelist list and the translated value ID tables **104***a* received from the partitions B_1, B_2. Consider FIG. **12**A for a discussion of processing in partition A_1. It is noted that in accordance with the present invention, the value IDs in each translated value ID table **104***a* received from the partitions B_1, B_2 will map to the same global ID or to "4", meaning that no translation was made in the respective B partition. For example, value ID 1 maps to global ID 1 in the table **104***a* received from partition B_1. Value ID 1 also maps to global ID 1 in the table **104***a* received from partition B_2 However, value IDs 2, 3, and 4 in the table **104***a* received from partition B_1 were not translated, so these value IDs map to "−1". On the other hand, value IDs 2 and 3 in the table **104***a* received from partition B_2 were (coincidentally) translated to global IDs 2 and 3, respectively. It is noted that the mapped pairs having global ID "−1" can be regarded as having non-matching values in the join operation (e.g. partition A_1 value ID 4/Doc ID 4). Those rows would be eliminated in the case of an inner join.

In an embodiment, using the tuple list **604** obtained (FIG. **6**) for partition A_1, then for each value ID in the tuple list: (1) if the value ID appears in one of the translated value ID tables **104***a*, then (2) copy the corresponding global ID from that table into a globalized list **108***a* for partition A_1, and (3) copy the corresponding Doc ID from the tuple list for all instances of the value ID. The globalized list **108***a* is then communicated to the recipient server. This procedure is repeated in partition A_2, with reference to FIG. **12**B using the tuple list **604** generated for partition A_2 and the translated value ID tables **104***b* received from partitions B_1 and B_2 to generate a globalized list **108***b*. The resulting globalized list **108***b* is then communicated to the recipient server.

Step **312**—Compile Combined Lists

The recipient server will receive the globalized lists **106***a*, **106***b* from respective partitions B_1, B_2. A compiled B list **112** can be created by concatenating the two globalized lists **106***a*, **106***b*. This is illustrated in FIG. **13**. The compiled B list **112** comprises pairs of Doc IDs and global IDs. The Doc ID identifies those rows among partitions B_1 and B_2 for which the actual values of the specified attribute (now identified by the global IDs) also occur in at least one of the partitions A_1, A_2. The figure also shows a compiled A list **114** for the A partitions, created by concatenating globalized lists **108***a*, **108***b*. The compiled A list **114** comprises pairs of Doc IDs and global IDs. The Doc ID identifies those rows among partitions A_1 and A_2 for which the actual values of the specified attribute (now identified by the global IDs) also occur in at least one of the partitions B_1, B_2.

Step **314**—Join the Compiled Lists

Still referring to FIG. **13**, a join operation is performed between the compiled A list **114** and the compiled B list **112**, where the join condition is based on the global ID attribute. In other words, the join operation is predicated on the global ID in the compiled A list **114** being equal to the global ID in compiled B list **112**. The join result **122** is shown in the figure.

A comparison of the join result **122** in FIG. **13** with the join result shown in FIG. **4**A will reveal that the two results are identical. The result obtained in FIG. **4**A was obtained by joining data tables A and B, which were not split. By comparison, the join result **122** in FIG. **13** was made on partitioned data tables A and B, while at the same time allowing for each database partition A_1, A_2, B_1, B_2 to employ a local dictionary on the specified attribute.

The above description illustrates various embodiments of the present invention along with examples of how aspects of the present invention may be implemented. The above examples and embodiments should not be deemed to be the only embodiments, and are presented to illustrate the flexibility and advantages of the present invention as defined by the following claims. Based on the above disclosure and the following claims, other arrangements, embodiments, implementations and equivalents will be evident to those skilled in the art and may be employed without departing from the spirit and scope of the invention as defined by the claims.

What is claimed is:

1. A method for a join operation between a first data table and a second data table based on a first attribute of the first data table and a second attribute of the second data table, the method comprising:

a computer processor in a first computer system generating reduction data for a first data partition, the first computer system being one among a plurality of first computer systems, the first data partition being one among a plurality of first data partitions that constitute the first data table and are distributed among the plurality of first computer systems, the reduction data comprising value IDs representative of actual values of the first attribute in the first data partition;

the computer processor sending the reduction data to a plurality of second computer systems which store a plurality of second data partitions that constitute the second data table;

the computer processor receiving a plurality of mappings from the plurality of second computer systems, each second computer system having value IDs from reduction data received from the plurality of first computer systems, each value ID being associated with a corresponding global ID that is common among the plurality of second computer systems, wherein a mapping in a given second computer system comprises a plurality of data pairs of a value ID and an associated global ID, wherein value IDs in the mapping are representative of actual values of the second attribute in the second data partition of the given second computer system; and

the computer processor generating a first globalized list comprising data pairs of a document ID from the first data partition paired with a global ID from one of the mappings received, wherein the value ID that is paired with the global ID represents an actual value of a first attribute of a data record in the first data partition identified by the document ID,

wherein a plurality of first globalized lists from one or more of the first computer systems are combined into a first compiled list,

wherein a plurality of second globalized lists from one or more of the second computer systems are combined into a second compiled list,

wherein the first and second compiled lists are joined based on global IDs in the first compiled list and the global IDs in the second compiled list.

2. The method of claim **1** wherein the value IDs in the reduction data for the first data partition are entries in a local dictionary stored in the first computer system.

3. The method of claim **1** further comprising the computer processor sending the globalized list to a recipient server, wherein the recipient server uses globalized lists received from the plurality of first computer systems to generate the first compiled list.

4. The method of claim **3** wherein the recipient server uses globalized lists received from the plurality of second computer systems to generate the second compiled list.

5. The method of claim **4** wherein the recipient server combines the first and second compiled lists based on the global IDs in the first compiled list and the global IDs in the second compiled list.

6. The method of claim **1** wherein each of the second globalized lists is generated using reduction data from each of the first data partitions.

7. A non-transitory computer readable storage medium having stored thereon computer executable program code, which when executed, will cause a computer processor in a first computer system to perform steps for a join operation between a first data table and a second data table based on a first attribute of the first data table and a second attribute of the second data table, the steps including:

generating reduction data for a first data partition, the first computer system being one among a plurality of first computer systems, the first data partition being one among a plurality of first data partitions that constitute the first data table and are distributed among the plurality of first computer systems, the reduction data comprising value IDs representative of actual values of the first attribute in the first data partition;

sending the reduction data to a plurality of second computer systems which store a plurality of second data partitions that constitute the second data table;

receiving a plurality of mappings from the plurality of second computer systems, each second computer system having value IDs from reduction data received from the plurality of first computer systems, each value ID being associated with a corresponding global ID that is common among the plurality of second computer systems, wherein a mapping in a given second computer system comprises a plurality of data pairs of a value ID and an associated global ID, wherein value IDs in the mapping are representative of actual values of the second attribute in the second data partition of the given second computer system; and

generating a first globalized list comprising data pairs of a document ID from the first data partition paired with a global ID from one of the mappings received, wherein the value ID that is paired with the global ID represents an actual value of a first attribute of a data record in the first data partition identified by the document ID,

wherein a plurality of first globalized lists from one or more of the first computer systems are combined into a first compiled list,

wherein a plurality of second globalized lists from one or more of the second computer systems are combined into a second compiled list,

wherein the first and second compiled lists are joined based on global IDs in the first compiled list and the global IDs in the second compiled list.

8. The non-transitory computer readable storage medium of claim **7** wherein the value IDs in the reduction data for the first data partition are entries in a local dictionary stored in the first computer system.

9. The non-transitory computer readable storage medium of claim **7** wherein the computer executable program code, which when executed, will further cause the computer processor to send the globalized list to a recipient server, wherein the recipient server uses globalized lists received from the plurality of first computer systems to generate the first compiled list.

10. The non-transitory computer readable storage medium of claim **9** wherein the recipient server uses globalized lists received from the plurality of second computer systems to generate the second compiled list.

11. The non-transitory computer readable storage medium of claim **10** wherein the recipient server combines the first and second compiled lists based on the global IDs in the first compiled list and the global IDs in the second compiled list.

12. The non-transitory computer readable storage medium of claim **7** wherein each of the second globalized lists is generated using reduction data from each of the first data partitions.

13. A first computer system comprising:

a computer processor;

a memory; and

executable program code stored in the memory to perform a join operation between a first data table and a second data table based on a first attribute of the first data table and a second attribute of the second data table, wherein the first data table is split into a plurality of first data partitions and the second data table is split into a plurality of second data partitions,

the memory storing one of the first data partitions,

the executable program code, which when executed by the computer processor, will cause the computer processor to:

generate reduction data for a first data partition, the first computer system being one among a plurality of first computer systems, the plurality of first data partitions being distributed among the plurality of first computer systems, the reduction data comprising value IDs representative of actual values of the first attribute in the first data partition;

send the reduction data to a plurality of second computer systems which store the plurality of second data partitions that constitute the second data table;

receive a plurality of mappings from the plurality of second computer systems, each second computer system having value IDs from reduction data received from the plurality of first computer systems, each value ID being associated with a corresponding global ID that is common among the plurality of second computer systems, wherein a mapping in a given second computer system comprises a plurality of data pairs of a value ID and an associated global ID, wherein value IDs in the mapping are representative of actual values of the second attribute in the second data partition of the given second computer system; and

generate a first globalized list comprising data pairs of a document ID from the first data partition paired with a global ID from one of the mappings received, wherein the value ID that is paired with the global ID represents an actual value of a first attribute of a data record in the first data partition identified by the document ID,

wherein a plurality of first globalized lists from one or more of the first computer systems are combined into a first compiled list,

wherein a plurality of second globalized lists from one or more of the second computer systems are combined into a second compiled list,

wherein the first and second compiled lists are joined based on global IDs in the first compiled list and the global IDs in the second compiled list.

14. The system of claim **13** wherein the value IDs in the reduction data for the first data partition are entries in a local dictionary stored in the first computer system.

15. The system of claim **13** wherein the computer executable program code, which when executed, will further cause the computer processor to send the globalized list to a recipient server, wherein the recipient server uses globalized lists received from the plurality of first computer systems to generate the first compiled list.

16. The system of claim **15** wherein the recipient server uses globalized lists received from the plurality of second computer systems to generate the second compiled list.

17. The non system of claim **16** wherein the recipient server combines the first and second compiled lists based on the global IDs in the first compiled list and the global IDs in the second compiled list.

18. The system of claim **13** wherein each of the second globalized lists is generated using reduction data from each of the first data partitions.

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